CHAPTER 6

STRUCTURAL DESIGN

6-1. Track Structure.

a. Design objective. Among its various functions, the track system serves to distribute the large, concentrated wheel loads longitudinally, laterally, and vertically away from the wheel contact area on the rail surface. A well designed, constructed, and maintained track will distribute the loads in a relatively uniform fashion, with each component supporting its share of the load. The role of the designer is to select a track structure (or changes to an existing track) so that the intended wheel loads will be properly supported, without overstressing any of the four main track system components: rail, ties, ballast, and subgrade.

b. Load distribution. As shown in figure 6-1, when a wheel is centered over a tie, the tie directly beneath the load will generally carry less than half of that wheel load, with the remainder supported by two ties on either side. Beneath the wheel, the pressures are distributed (reduced) approximately as shown in figure 6-2. With a wheel-rail contact area of about 1/2 square inch, stresses are reduced from 60, 000 psi at the top of the rail to about 10 psi at the depth of the subgrade surface. While the actual load and pressure distributions will vary with wheel load, track design, and track condition, the two figures illustrate a realistic case for good track.

c. Behavior under load. It is important to note that while track construction is relatively simple, its behavior under load is not. An improvement (or increase in strength) in one track component may cause an increased load on another. This is a common occurrence and is illustrated in the example in appendix C, using the TRACK program.

6-2. Track Design Methods.

a. Computer Programs Available. Computer programs for basic track structure design are available through the PCASE Bulletin Board and the Army Transportation Systems Center (CEMRDED-TT). Their use is recommended. Appendix C provides guidance on the use of one structural analysis program.

b. Manual Design Procedure. If computer programs are not accessible or a computer is unavailable, the design procedure in paragraph 6-3 may be used as an alternative. A disadvantage of this method, however, is that very little data exists to correlate the value of track modulus with the properties of individual rail support components: ties, ballast, and subgrade.

6-3. Area Design Procedure (Modified).

a. Applying the AREA Method to Military Track.

(1) The AREA method leaves several choices and judgments open to designers, to be set according to situation and policy. And like most AREA criteria, the method is also oriented toward those commercial lines which carry medium to heavy traffic volumes (more than 10 million gross tons per year) and operate at medium or higher speeds (more than 40 mph).

(2) The guidance below is based on recognizing that most military track operates at relatively low traffic volumes (less than 5 million gross tons per year) and at relatively low speeds (less than 25 mph), and uses jointed, rather than continuously welded, rail.

(3) For unusual cases where yearly traffic frequencies are expected to exceed 5 million gross tons, designers may follow the method directly from chapter 22 of the AREA manual.

b. Basis for Design.

(1) The AREA track design method is based on extensive field and laboratory testing conducted between 1914 and 1940. The committee supervising the tests and evaluations was led by Professor Arthur Talbot of the University of Illinois, whose name is often used when referring to the tests and findings.

(2) One of the Talbot Committee's findings was that, when subject to a large number of load repetitions ("millions of groups of car wheels"), the greater the vertical rail deflection under those loads, the faster the track condition deteriorated. From the data and observations collected, the AREA then developed a track design method based on limiting or controlling vertical rail deflection.

(3) Figure 6-3 illustrates the general relationship between track deflection and track performance over long time periods. The design criteria in this section are based on limiting the deflection of main running tracks to 0.3 inches and of auxiliary, storage, spur, and light use tracks to 0.4 inches.

(4) The AREA track design method uses the beam-on-elastic-foundation model. In this model, the track has two components: the beam, which is the rail, and the elastic foundation, which represents everything below the rail combined. The

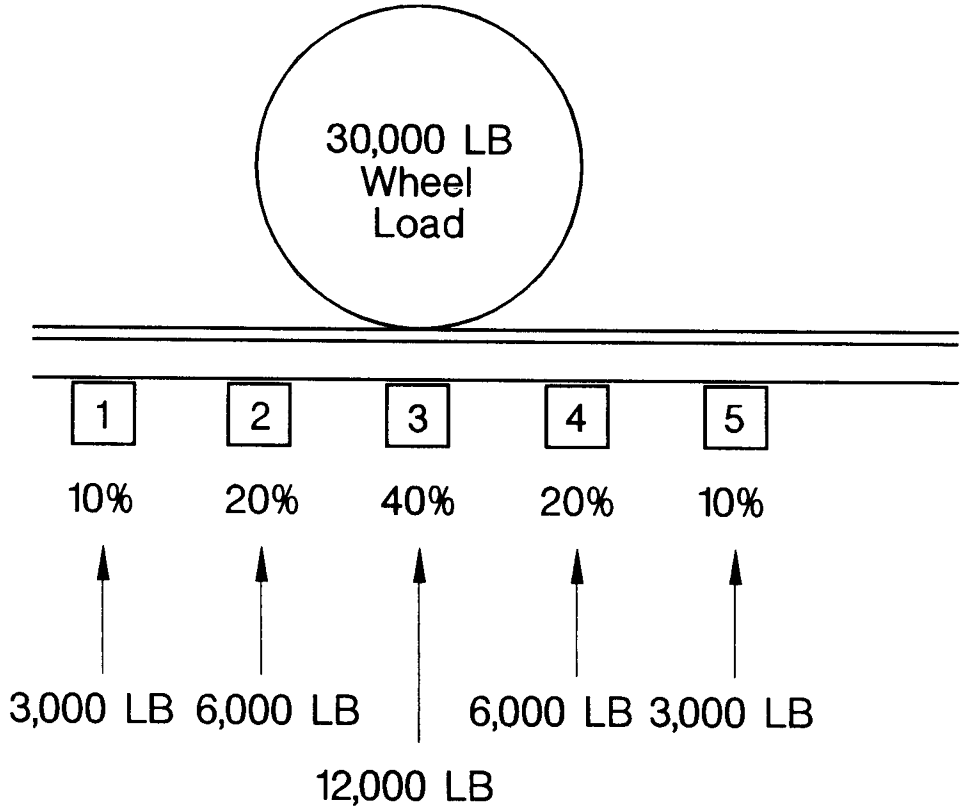


Figure 6-1. Example load distribution along the track.

basic expression in the model relates three main variables: the load on the rail, the stiffness of the track system, and the amount of vertical rail deflection, as follows:

$$Y = \frac{P}{(64\,EIu^3)^{0.25}} \qquad \text{(eq 6-1)}$$

Y = vertical rail deflection at a point (inches).
P = applied wheel load (including contributions from adjacent wheels) (lbs).
EI = stiffness of the rail, where:
E = modulus of elasticity for steel (30 x 106 psi).
MI = vertical moment of inertia of the rail section (inches4).
u = stiffness of rail support, or track modulus (psi).

In this equation, EI represents the stiffness of the abeam" and u the stiffness of the "elastic foundation."

c. Design Load and Wheel Spacing.

(1) Select the design wheel load from table 2-2, based on the most common, heaviest car expected to travel over the track.

(2) Figure 6-4 shows the two most common wheel configurations. Most cars have 2-axle trucks and the design wheel configuration is that in drawing (a), with an average 75-inch wheel spacing. The 140-ton series flat cars (for carrying M-1 tanks and other heavy vehicles) and some 100-ton flat cars have 3-axle trucks; their design wheel configuration is that in drawing (b), with 66-inch wheel spacing.

(3) The track is evaluated assuming that a wheel is centered over a tie, with an adjacent wheel on either side contributing to the loads, deflections, and stresses-as occurs when two cars are coupled together. Referring to figure 6-4(a), the maximum tie, ballast, and subgrade loads will occur under wheels 2 and 3, while the maximum rail bending stress will occur at wheels 1 and 4. For the wheel configuration in figure 6-4(b), the maximum. tie, ballast, and subgrade loads will occur under wheels 2 and 5, while the maximum rail bending stress will occur at wheels 1 and 6.

(4) The effect of wheels farther than 100 inches from the design wheel is negligible.

d. Select Trial Track Modulus (u). The track modulus values listed in table 6-1 are suggested starting points for design. In the table, track type "main" refers to main running tracks, while "auxiliary" includes sidings, wyes, loading, spur, storage, interchange, and light use tracks.

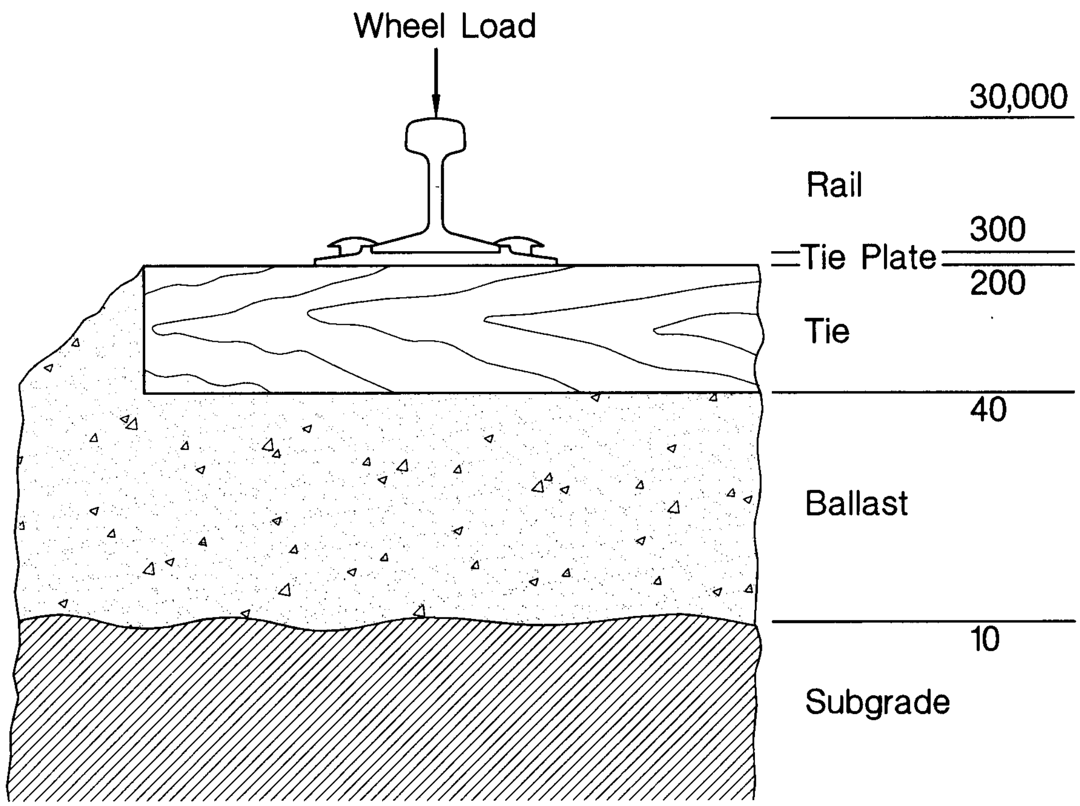
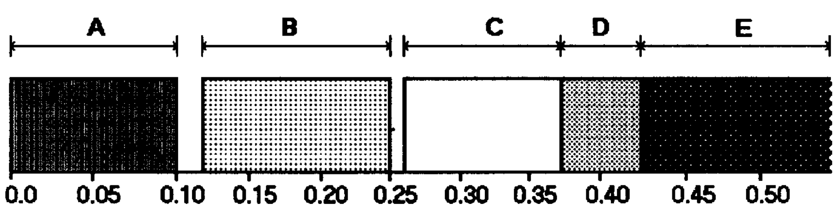


Figure 6-2. Example vertical pressure reduction through the track.



Maximum Track Deflection Under Load (inches)

Range	Long Term Track Performance
A ----------	Excessively stiff track.
B ----------	Track of heavier construction which will hold up well under large traffic volumes (> 15 MGT).
C ----------	Track suitable for lower traffic volumes (< 15 MGT).
D ----------	Sidings and other auxiliary tracks on low traffic lines.
E ----------	Track which will deteriorate quickly: only suitable for occasional movements with cars less than 100 tons capacity.

Note: Deflections do not include any play or looseness between track components.

Figure 6-3. Relationship between maximum track deflection and long term track performance.

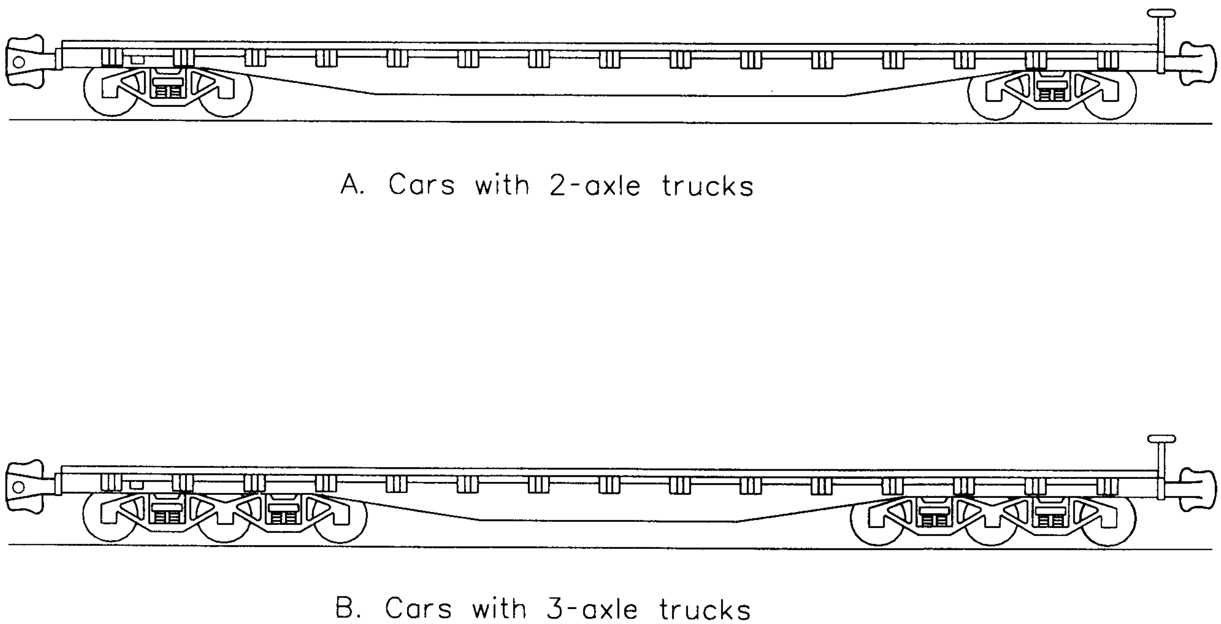


Figure 6-4. Design wheel configurations.

Table 6-1. Suggested Design Track Modulus Values.

	Design Wheel Load Range (1, 000's of pounds)					
	20-25	25-30	30-35	35-40	40-45	45-50
Track Type						
Main	1500	1800	2000	2300	2600	2900
Auxiliary	1200	1300	1500	1700	2000	2200

e. Select Rail Size.

(1) Use the following equation to determine a minimum rail weight:

$$W_o = 315 - \frac{21200}{\frac{(P)}{1120}(\alpha) + 67} \qquad \text{(eq 6-2)}$$

W_o = Weight of rail (lbs/yd)
P = Design wheel load (lbs)
α = Impact factor:
α = 1, where design operating speed is 25 mph or less.
α = 1.4, where design operating speed is more than 25 mph.

(2) Select a rail section from table 6-2 of equal or greater weight than calculated above.

Table 6-2. Rail Sections.

Rail Section	Moment of Inertia: I (inches^4)	Section Modulus to Base: Z_b (inches^3)
100 ARA-B	41.3	15.7
112 RE	65.5	21.8
115 RE	65.6	22.0
130 RE	77.4	25.5
132 RE	88.2	27.6
133 RE	86.0	27.0
136 RE	95.4	28.4

f. Determine Moment and Loading Coefficients.

(1) The moment and loading coefficients account for the affects of wheels adjacent to the

design wheel. Adjacent wheels reduce rail moment and increase tie, ballast, and subgrade load.

(2) Calculate X_1 using equation 6-3. (X_1 should normally range between 28 and 40):

x_1 = Distance from design wheel load to point of zero bending moment (inches).

$$X_1 = 82 \sqrt[4]{\frac{I}{u}} \qquad \text{(eq 6-3)}$$

I = Vertical moment of inertia of rail section (inches^4).
u = stiffness of rail support, or track modulus (psi).

(3) Determine coefficients Cm and Cd as follows:

(a) For most design situations, and for cars with either 2-axle or 3-axle trucks, the rail moment coefficient (Cm) can be taken as 0.8.

(b) The load coefficient Cd can be taken from the following table:

X1 =		28	30	32	34	36	38	40
Design Wheel	66:	1.24	1.30	1.36	1.44	1.54	1.62	1.70
Spacing:	75:	1.08	1.15	1.22	1.30	1.36	1.42	1.50

g. Check Rail Bending Stress. Use equation 6-4 to check that rail bending stress is less than 32, 000:

$$f_o = \frac{(0.318\, P_d C_m X_1)}{Z_b} \qquad \text{(eq 6-4)}$$

f_o = Maximum flexural stress (psi).
P_d = Dynamic (design) wheel load (lbs).
C_m = Moment coefficient.
x_1 = Distance from wheel load to point of zero bending moment (inches).
Z_b = Section modulus of rail base, from table 6-2 (inches).

h. Ties and Tie Spacing.

(1) Choose a trial tie spacing and calculate the maximum rail seat load using equation 6-5:

$$q_o = \frac{0.39\, P_d C_d S_1}{X_1} \qquad \text{(eq 6-5)}$$

q_o = Maximum rail seat load (lbs).
P_d = Dynamic (design) wheel load (lbs).
C_d = Load coefficient for adjacent wheels.
S = Tie spacing (inches).
X_1 = Distance from wheel load to point of zero bending moment (inches).

(2) Select tie size, either 6" x 8" x 8.5 feet or 7" x 9" x 8.5 feet.

(3) Check tie bending stress using equation 6-6a

$$\text{For 6 x 8 Ties: } f_t = \frac{q_o}{29} \qquad \text{(eq 6-6a)}$$

or 6-6b, and ft = 1100 psi as a suggested limit:

$$\text{For 7 x 9 Ties: } f_t = \frac{q_o}{52} \qquad \text{(eq 6-6b)}$$

f_t = Flexural stress on underside of tie below rail seat (psi).
q_o = Maximum rail seat load (lbs).
(4) If ft >1100, choose a larger tie size or decrease tie spacing.

i. Ballast and Subgrade.

(1) Determine ballast surface stress from equation 6-7, with Pm = 6-5 psi as a suggested limit:

$$Pm = \frac{q_o}{A_b} \qquad \text{(eq 6-7)}$$

P_m = Ballast surface stress (psi).
q_o = Maximum rail seat load (lbs).
A_b = Effective bearing area of 1/2 tie on ballast (in^2).
For 6 x 8 ties, Ab = 270.
For 7 x 9 ties, Ab = 312.

(2) If P_m exceeds 65 psi, choose a larger tie and/or decrease tie spacing.

(3) Select design subgrade bearing capacity (p_c) according to results of soil tests, the guidance in paragraph 6-5d, or other data. (In the absence of other guidance, the design bearing capacity for cohesive soils may be the same as the unconfined compressive strength.)

(4) Determine ballast depth from equation 6-8:

h = Ballast depth in inches.
P_m = Ballast surface stress (psi).
P_c = Design subgrade bearing capacity.

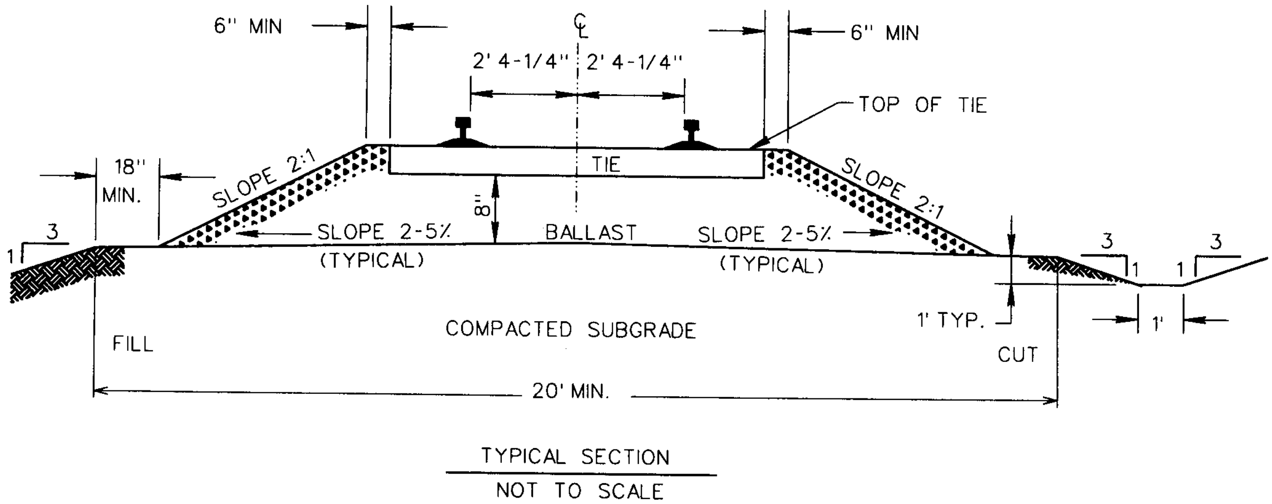
6-4. Roadway.

The roadway is the strip of land containing the track, ditches, and other facilities needed for the operation of the railroad. When planning a route, roadway width can be estimated from the standard cross sections shown in figures 6-5 through 6-11.

6-5. Subgrade.

a. Subgrade Stability and Tack Performance. The subgrade is the prepared earth on which the railroad ballast section and track structure are built. If the subgrade does not have sufficient stability, it will be impossible to maintain proper track alignment, profile (surface), and cross level.

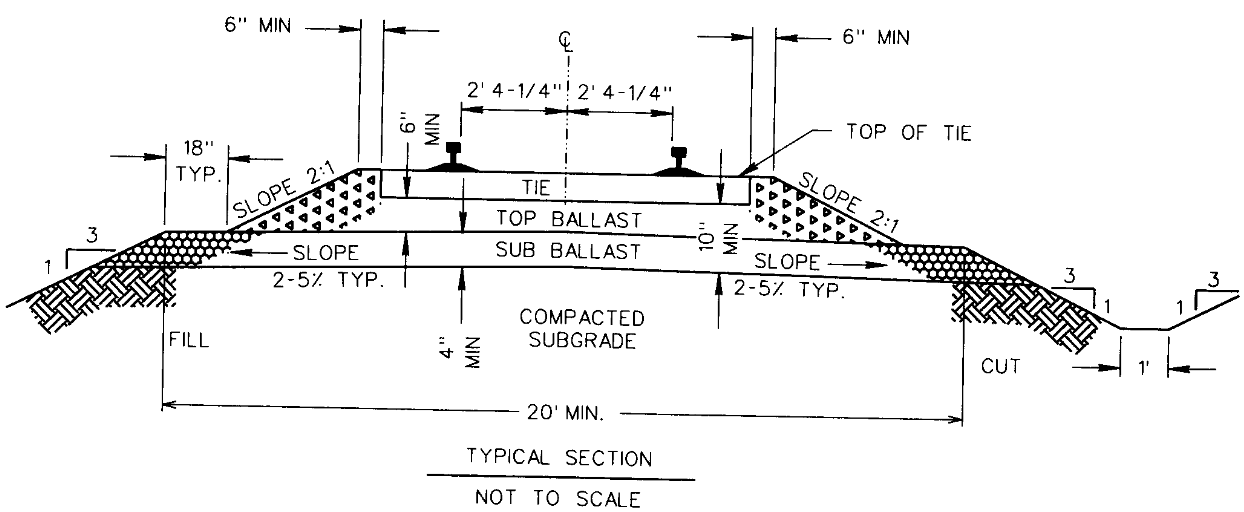
b. Soil Investigation. Prior to initial design of the track structure, a geotechnical investigation should be performed along the proposed alignment to determine soil type, strength, bearing capacity, location of groundwater tables, natural water content, and compaction characteristics. Additional geotechnical borings, laboratory testing, and engineering analysis will be required in areas where bridges or other special structures are to be constructed. Chapter 1, Part 1 of the AREA Manual



NOTES:

1. DEPTH OF BALLAST TO BE USED WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.
2. MINIMUM BALLAST DEPTH IS 8 INCHES BELOW BOTTOM OF TIE.
3. CUT OR FILL ACCORDING TO LOCAL CONITIONS.

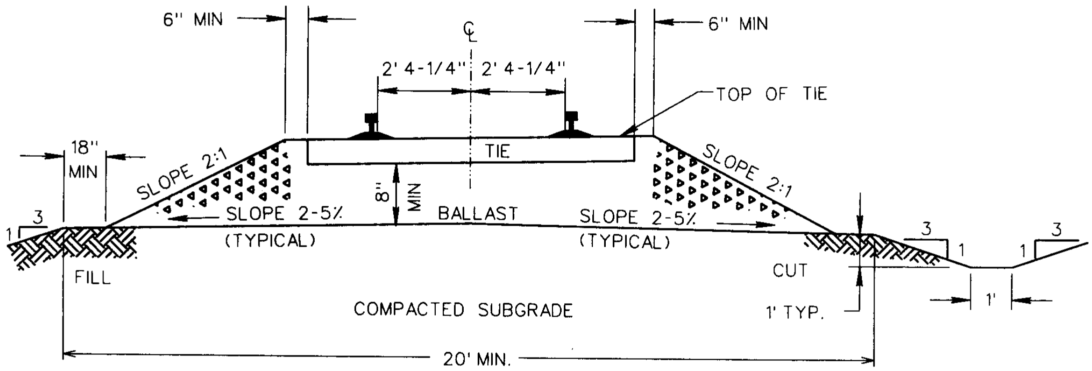
Figure 6-5. Typical cross section-tangent track.



NOTES:

1. DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.
2. MINIMUM DEPTH OF BALLAST IS 10 INCHES BELOW BOTTOM OF TIE
3. THICKNESS OF BALLAST AND SUBBALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.
4. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

Figure 6-6. Typical cross section with sub-ballast layer-tangent track.

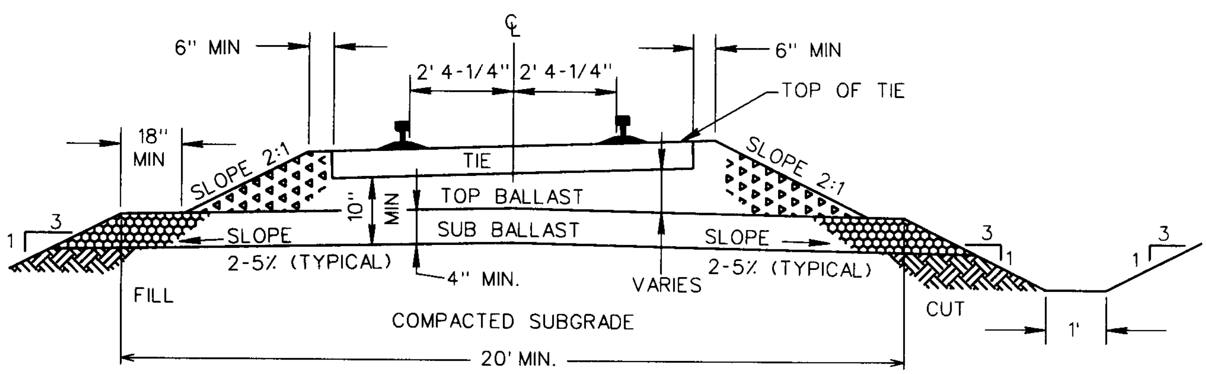


TYPICAL SECTION
NOT TO SCALE

NOTES:

1. **DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.**
2. **MINIMUM DEPTH OF BALLAST IS 8 INCHES BELOW THE BOTTOM OF THE TIE AT THE LOW (INSIDE) RAIL OF THE CURVE.**
3. **ON CURVES OF 6 DEGREES OR GREATER A BALLAST SHOULDER WIDTH OF 8 INCHES SHOULD BE USED.**
4. **CUT AND FILL ACCORDING TO LOCAL CONDITIONS.**

Figure 6-7. Typical cross section-curved track.

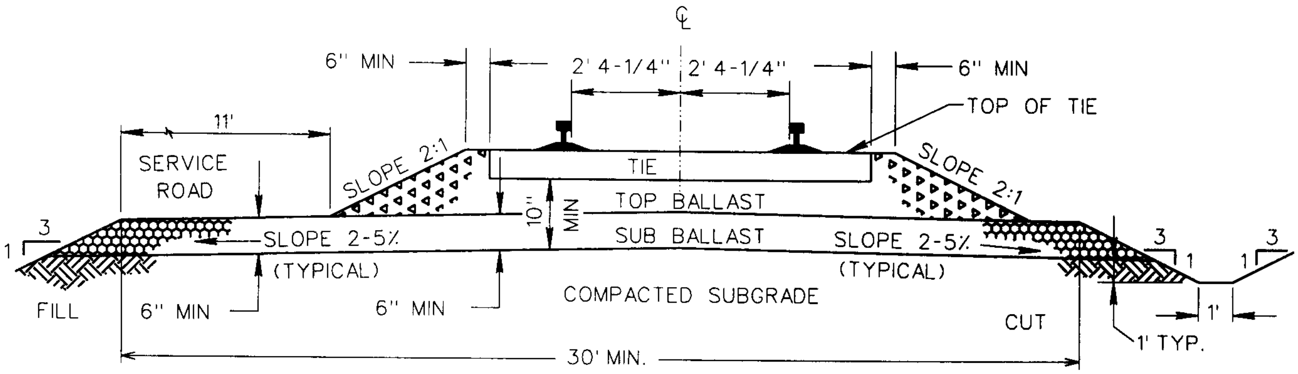


TYPICAL SECTION
NOT TO SCALE

NOTES:

1. **DEPTH OF BALLST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.**
2. **MINIMUM DEPTH OF BALLAST/SUBBALLAST IS 10 INCHES BELOW BOTTOM OF TIE.**
3. **THICKNESS OF BALLAST AND SUBBALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.**
4. **ON CURVES OF 6 DEGREES OR GREATER A BALLAST SHOULDER WIDTH OF 8 INCHES SHOULD BE USED.**
5. **CUT OR FILL ACCORDING TO LOCAL CONDITIONS.**

Figure 6-8. Typical cross section with sub-ballast layer-curved track.

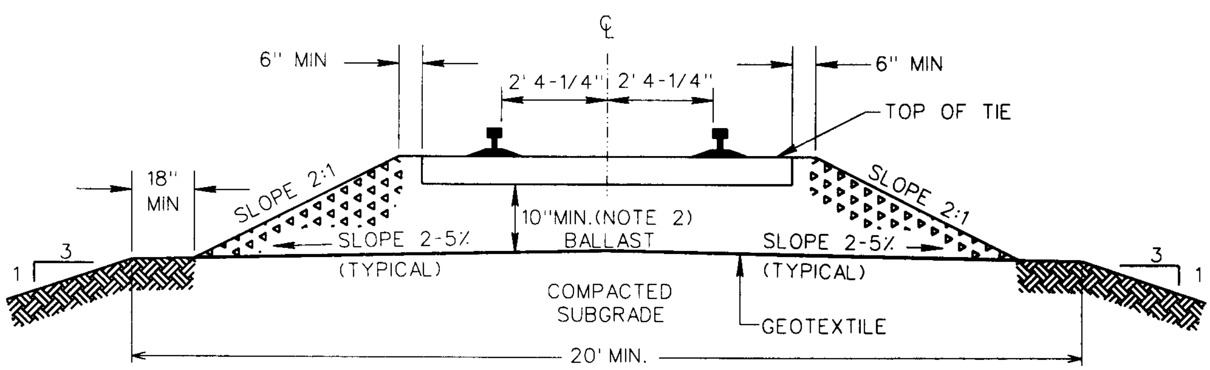


TYPICAL SECTION
NOT TO SCALE

NOTES:

1. **USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE BALLAST DEPTH FOR EACH SITE.**
2. **TO BE USED ONLY WHERE A SERVICE ROAD IS REQUIRED. SERVICE ROAD TURN AROUND REQUIRED EVERY 2, 000 FEET.**
3. **FOR USE WITH SERVICE ROAD, SUBBALLAST MATERIAL WILL BE AGGREGATE-SOIL MIXTURE REQUIRMENTS OF ASTM D-1241, TYPE 1, GRADUATION A, B, C, OR D.**
4. **SUBBALLAST WILL BE A MINIMUM OF 6 INCHES DEEP AND COMPACTED AT LEAST 90/ OF THE CE 55 MAXIMUM DRY DENSITY.**
5. **CUT AND FILL ACCORDING TO LOCAL CONDITIONS.**

Figure 6-9. Typical cross section-track with adjacent service road.

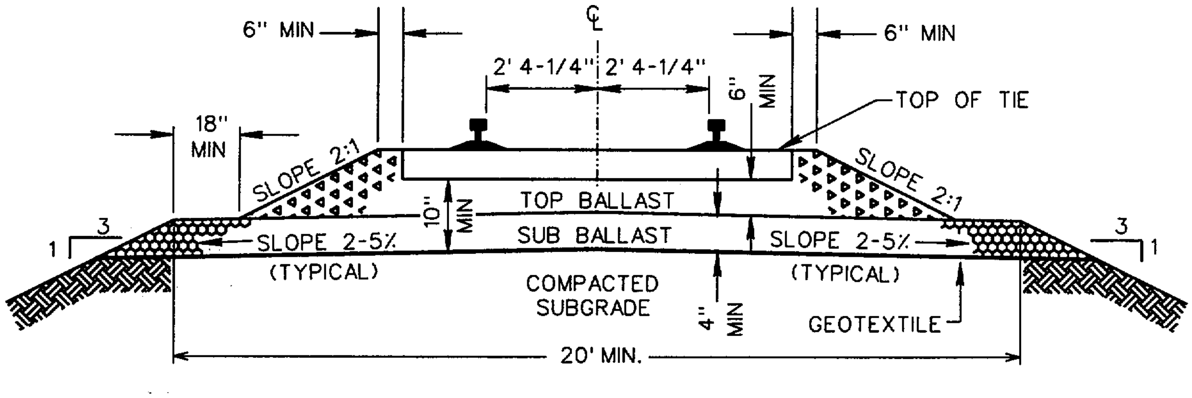


TYPICAL SECTION
NOT TO SCALE

NOTES:

1. **DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.**
2. **MINIMUM DEPTH OF BALLAST/SUBBALLAST IS 10 INCHES BELOW THE BOTTOM OF TIE AT THE LOW (INSIDE) RAIL OF THE CURVE WITH AREA GRADATION 5.12" MINIMUM DEPTH WITH AREA GRADATIONS 3, 4, AND 4A.**
3. **GEOTEXTILE TO MEET THE REQUIREMENTS OF CEGS 02274.**
4. **GEOTEXTILE INSTALLATION ON CURVES WILL BE SIMILAR.**

Figure 6-10. Typical cross section-track with geotextile.



TYPICAL SECTION
NOT TO SCALE

NOTES:

1. **DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.**
2. **MINIMUM DEPTH OF BALLAST/SUBBALLAST IS 10 INCHES BELOW BOTTOM OF TIE AT THE LOW (INSIDE) RAIL OF THE CURVE WITH AREA GRADATION 5. 12" MINIMUM DEPTH WITH AREA GRADATIONS 3, 4, AND 4A.**
3. **THICKNESS OF BALLAST AND SUBBALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.**
4. **GEOTEXTILES TO MEET THE REQUIREMENTS OF CEGS-02274.**
5. **GEOTEXTILE INSTALLATION ON CURVES WILL BE SIMILAR.**

Figure 6-11. Typical cross section with sub-ballast layer-track with geotextile.

provides recommendations for geotechnical investigations.

c. Design of Cuts and Fills and Subgrade Preparation. Chapter 1, Part 2 of the AREA manual provides recommendations for design of cuts and fills and subgrade preparation. The AREA manual indicates soils types and their suitability as railroad subgrades.

d. Track Structure Design Bearing Capacity-Cohesive Soils. For cohesive soils, and for track expected to carry the usual military traffic level of less than 5 million gross tons per year, design bearing capacity for the track structure may be set at the soil's unconfined compressive strength at its natural water content. For unusual cases, where annual traffic volumes are projected at higher than 5 million gross tons, 80% of the unconfined compressive strength may be used as the design bearing capacity.

e. Soil Stabilization. Information on the use of soil stabilization and the design and construction of soil stabilized subgrades is presented in TM 5-822-4/AFJMAN 321019. Especially in frost areas, soil stabilizers should be used with caution and only after intensive laboratory testing, including a frost susceptibility test and a freeze-thaw durability test.

6-6. Frost Design Modifications.

a. Frost Heave Conditions. Frost heaving is the rising of the soil due to the growth of ice lenses or ice segregation during freezing. There are three basic conditions which must be present for ice segregation to occur: a frost susceptible soil, a source of water, and freezing temperatures. A change in any of the three conditions will affect the amount of heave.

b. Identifying Frost Susceptible Soils. For design purposes, the potential for ice segregation is often expressed as a function of grain (or particle) size. Most organic, nonuniform soils containing three percent or more by weight of particles smaller than 0.02 mm are considered frost susceptible. Gravels, well graded sands and silty sands (especially those approaching the theoretical maximum density curve) that contain 1.5 percent to 3 percent of particles smaller than 0.02 mm should be considered possibly frost susceptible and subject to laboratory frost-susceptibility tests. Considerable ice segregation can be expected in uniform sandy soils with greater than 10 percent smaller than 0.02 mm. Figure 6-12 illustrates a method for determining the frost susceptibility of soils.

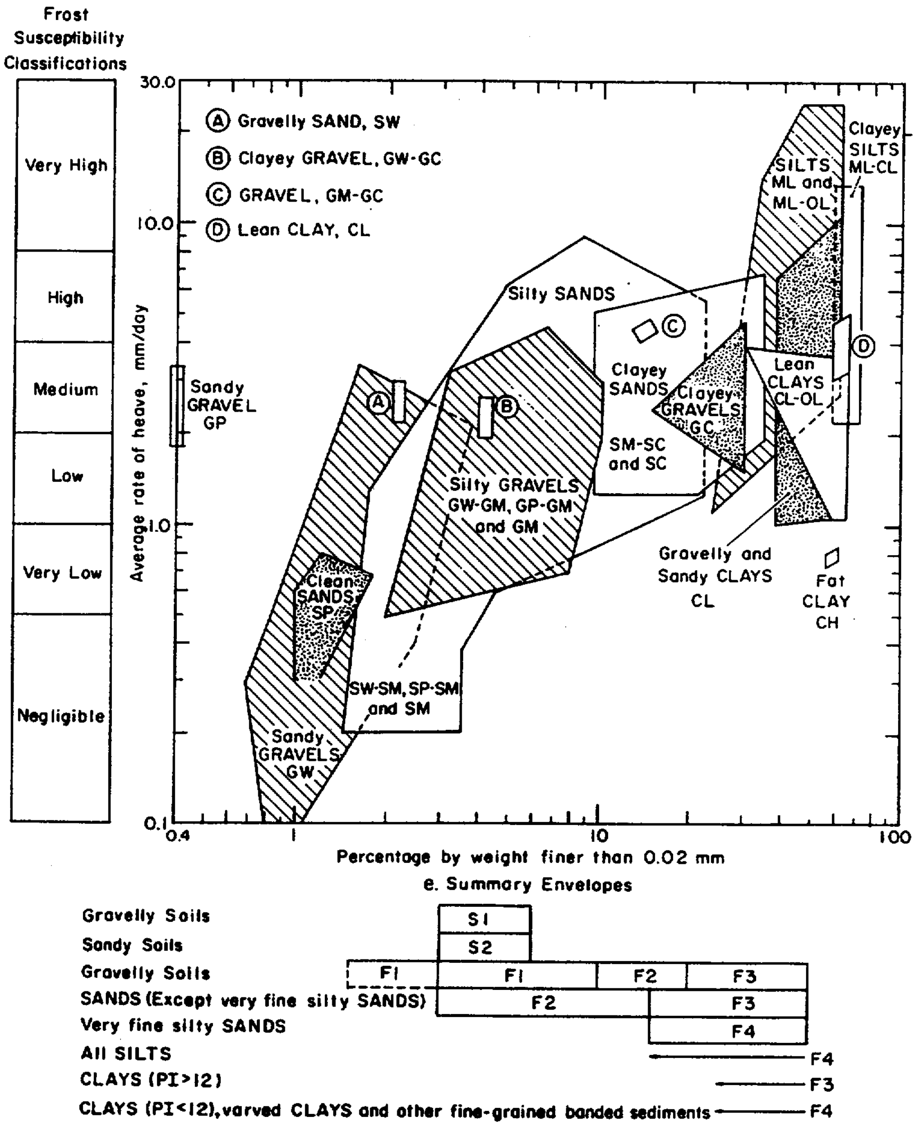


Figure 6-12. General method for determining the frost susceptibility of soils.

c. Water Source. Usually, the water source will e an underlying groundwater table, a perched aquifer or infiltration from the overlying layers.

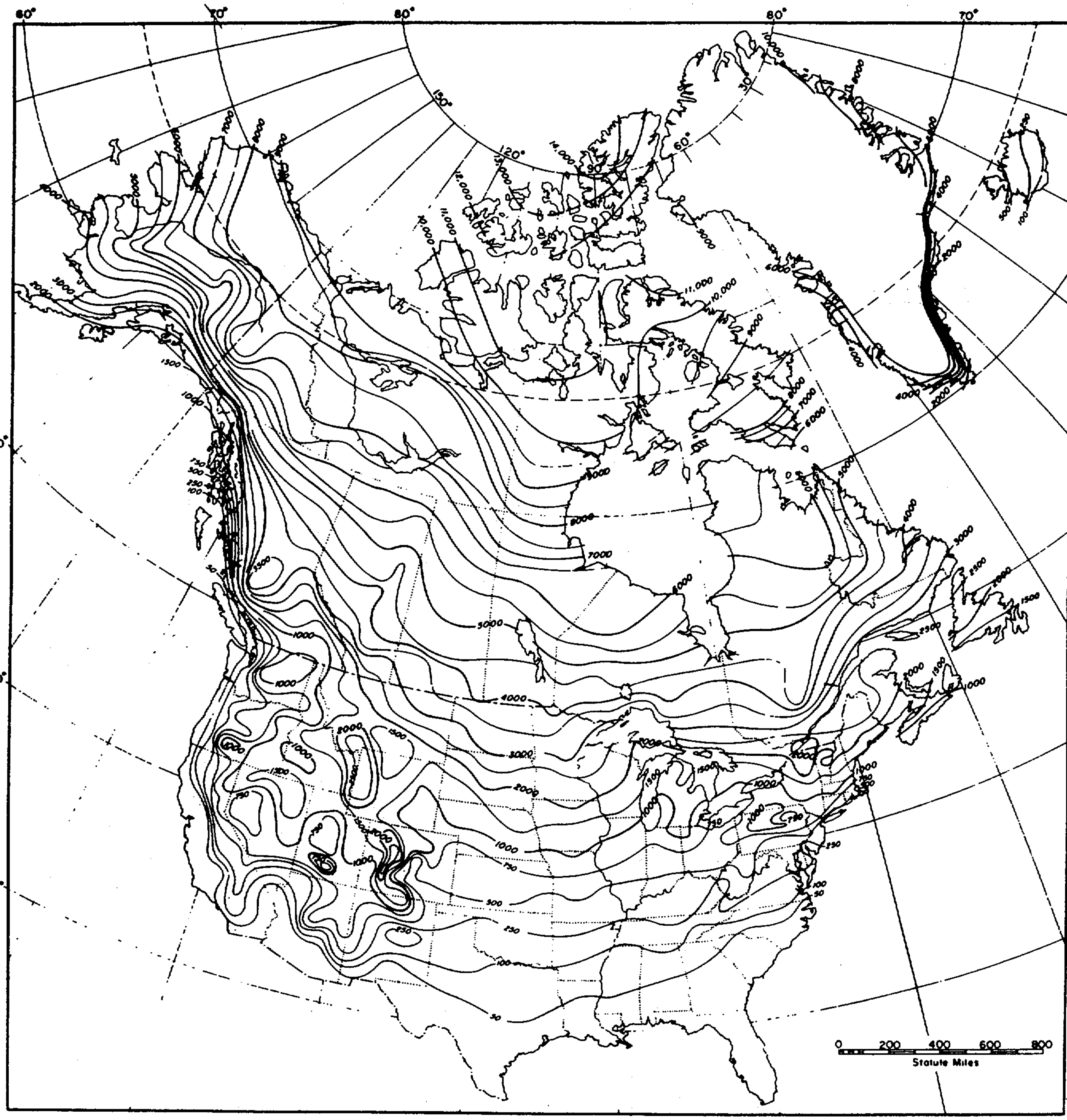
d. Frost Depth. Future track maintenance costs re reduced if the design depth of frost below the top of the ballast is at least 60 percent of the expected local frost depth. The expected frost depth should be established using local records, experience or building practices. If these are unavailable, use the procedures in TM 5-852-6/AFR 8-19, chapter 6.

e. Alternate Frost Depth Procedure.

(1) This procedure may only be used for fine rained silty soils of relatively uniform composition at different depths.

(2) Determine the Air Freezing Index-the number of degree days (above and below 32°F) between the highest and lowest points on the cumulative degree day curve for a freezing season. Or the design air freezing index use the three coldest years in the last thirty years of record, or use the average index and multiply it by 1.75. (If fewer than thirty years of data are available, the air freezing index for the coldest year in the last ten-year period may be used). If local records are unavailable use the values directly from figure 6-13.

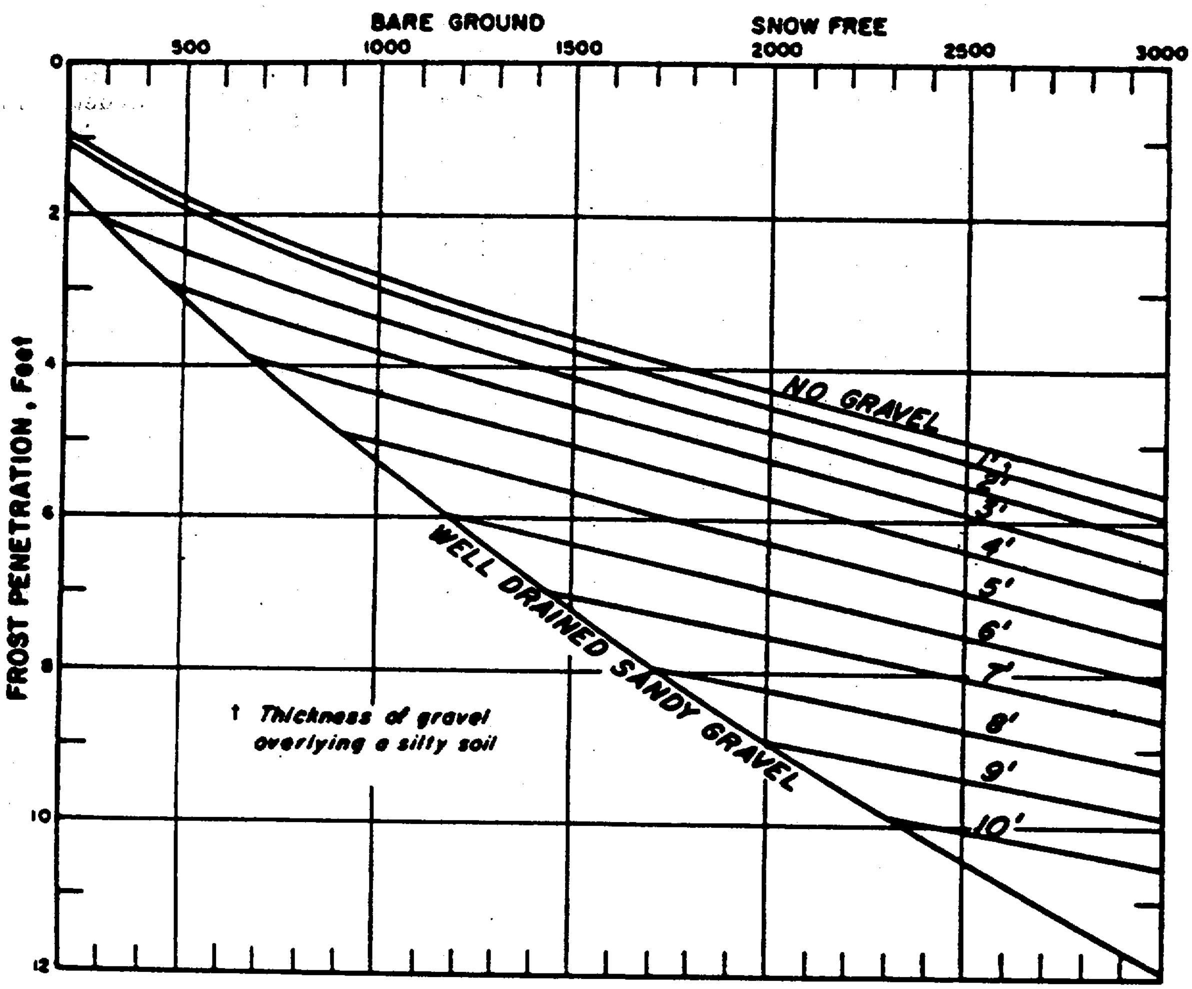
(3) Determine the frost depth using figure 6-14. The gravel thickness in this figure is the total depth of ballast and subballast. Multiply the frost penetration



Distribution of design air freezing indices in North America.

Figure 6-13. Design air freezing indexes in North America.

AIR-FREEZING INDEX, Degree-days



Relationship between air-freezing index frost penetration into a granular soil overlying a fine-grained soil

Figure 6-14. Air freezing index/Surface cover/Frost penetration relationship.

frost penetration value by 0.6. If the resulting number is smaller than the gravel thickness, then there is an adequate amount of ballast and subballast in the cross section. If it is larger, additional ballast and/or sub-ballast should be added and the thickness recalculated.

f. Alternate Design Procedure. An alternate method of designing for the effects of frost is to reduce the effective strength of the soil to compensate for the thaw-weakening period (similar to a reduced-strength pavement design).

g. Methods for Reducing Frost Effects.

(1) Additional Ballast/Sub-ballast. If more than 40 percent of the total frost depth is in the frost susceptible subgrade, nonfrost susceptible material (clean ballast or sub-ballast) must be added to the roadbed.

(2) Geotextiles. Geotextiles can be used to prevent particle migration at the subgrade/subballast interface during the spring thaw. Contamination of an otherwise clean ballast and subballast by subgrade soil can turn a nonfrost susceptible material into a frost susceptible material.

(3) Insulating Material. Frost heaving may be reduced or eliminated by the use of insulating materials. This may be particularly useful in areas with deep seasonal frost which lack nonfrost susceptible soils and in areas with varying subgrade soil conditions that may result in differential heaving. Expanded and extruded polystyrene foam boards are the two most commonly used synthetic insulations. Extruded polystyrene is generally the most popular. In some instances, organic material such as peat, bark, wood chips or timbers and mineral materials such as slag or gravel have also been used. Placement of the insulation can be between the ballast and sub-ballast, sub-ballast and the subgrade or anywhere in between. However, the insulation should be placed deep enough in the cross section to prevent damage by maintenance equipment. In general, a minimum depth of 24 in. is recommended. Results of field and laboratory tests have shown that extruded polystyrene retains its thermal properties and does not absorb a significant amount of moisture if the board is protected from deformation. Therefore, the thickness of the cover above the insulation is usually determined by the vertical stresses caused by the dead and live loads and is limited to 1/5 of the compressive strength of the insulating material. Extruded polystyrene is commercially available in compressive strengths of 40, 60 and 115 psi. Physical properties, available' thicknesses and sheet sizes are available from manufacturers specifications. TM 5-852-6/AFR 88-19, chapter 6 provides calculations of frost depth where insulation is used

h. Transition Zones. A gradual transition is required between areas with significantly different frost heave behavior. The transition distributes differential heave over a distance and thus reduces its detrimental affects. Transitions between cuts and fills and at culvert crossings and bridge approaches are typically 75 to 100 feet long.

i. Construction Procedures. Subgrade will be excavated and scarified to a predetermined depth based on field conditions, and then wind-rowed and bladed to achieve adequate blending. This helps to insure a high degree of uniformity of soil conditions and eliminate any isolated pockets of soil with higher or lower frost susceptibility. It may be necessary to remove isolated pockets of either low or high frost susceptible material. In these cases, the soil should be excavated to the full frost depth and replaced with the surrounding soil. Stones (6-in. in diameter or larger) or large roots must be removed from any fill in the full depth of the frost penetration. This includes any stones encountered during subgrade preparation. Failure to remove these items can result in track roughness as the stones and roots are gradually heaved upward. In rock excavations, positive drainage should be supplied so that no pockets of water are left in the zone of freezing. The irregularity of the isolated pockets may lead to nonuniform heaving. At the transition between cut and fill sections, transition sections should be used as previously discussed. Frequently, rock joints and fractures are full of frost susceptible soil. Rock joints or fractures encountered in the subgrade should be cleaned out to the full depth of frost penetration and these joints replaced with nonfrost susceptible material.

6-7. Drainage.

a. Importance. Although not a component of the track or roadbed, drainage (or lack of it) can have a major impact on track strength and longevity. Without proper drainage, track will fail to perform as designed or intended.

b. Design guidance. TM 5-820-4/AFJMAN 32-1016 will be used for the design and construction of drainage structures, except as modified by the following paragraphs.

c. Side Ditches.

(1) Most commonly, drainage is provided by open ditches running parallel to the track. In terminals and in other level areas, subdrainage or other alternative drainage designs will be required.

(2) To prevent a significant loss of strength in the subgrade, side ditches must provide ample capacity and flow rate. The size of ditches will be based on the expected rainfall runoff and the contribution from other drainage which may empty into the ditches. Guidance for estimating runoff and ditch size may be found in TM 5-820-4.

(3) To provide adequate capacity, side ditches will be designed for a 10-year storm. To provide an adequate flow rate, the minimum gradient for side ditches will be b.30 percent.

(4) While not a desirable practice, there are some areas where the bottom of the ballast section cannot be installed or raised above the surrounding ground level, and standard side ditches cannot be dug (or would not provide sufficient flow). In these cases, subdrainage will be installed as shown in figure 6-15.

d. Culverts.

(1) The AREA manual provides design criteria and specifications for railroad culverts. AH culvert pipe will conform to current AREA or ASTM recommendations or specifications for culvert pipe under railroads.

(2) A minimum cover of 2.5 ft should be provided from the bottom of the tie to the top of the culvert

.

6-8. Geotextiles.

a. Application Under Track. Geotextiles are sometimes used under the track to provide for filtration and/or separation of ballast and subgrade or ballast and sub-ballast, or drainage functions. Common locations for the installation of a geotextile under track are:

(1) Highway-railroad grade crossings.

(2) Locations with poor subgrade.

(3) When rebuilding track with a history of excessive loss of profile (surface) and frequent track maintenance requirements.

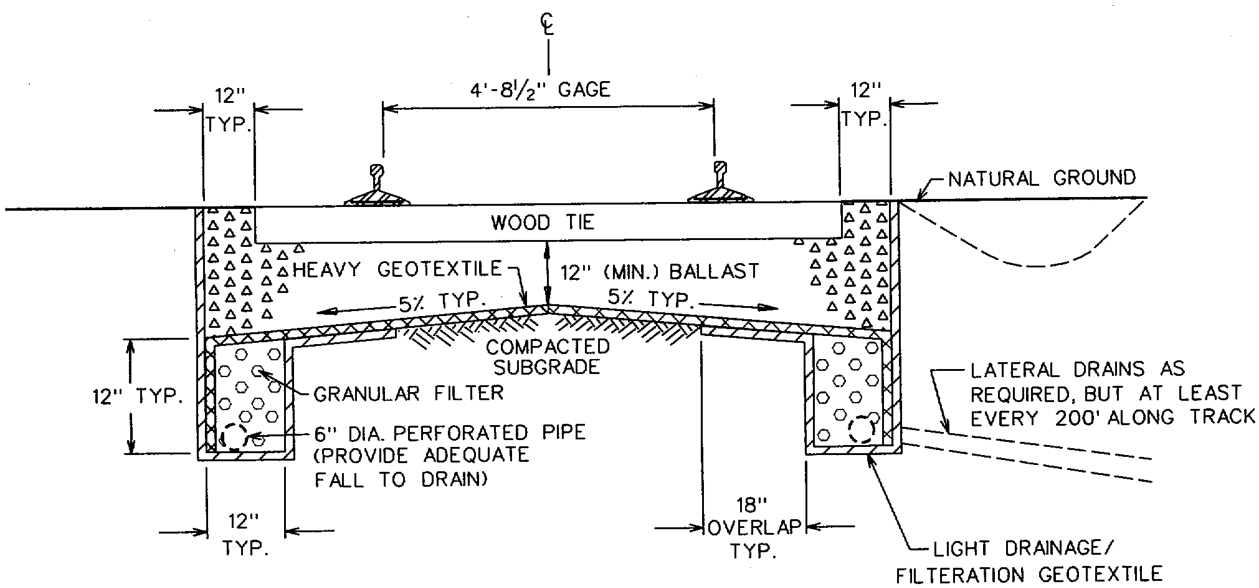
(4) Turnouts. (see fig 6-16.)

(5) Bridge approaches. (see fig 6-17.)

(6) Rail crossings. Recent industry studies have shown that geotextiles have not always been effective under track. Thus, before deciding to install a geotextile, a thorough analysis of the site must be done to assure that a geotextile will accomplish its intended purpose.

b. Material and Installation Specifications. Geotextiles, and their installation, will conform with the specifications in the AREA manual.

c. Drainage Applications. Lighter weight geotextiles are often useful for drainage applications outside of the track structure, especially in subdrainage.



DRAWING NOT TO SCALE

Figure 6-15. Required subdrainage where surrounding natural ground is above bottom of ballast and open side ditches cannot be installed.

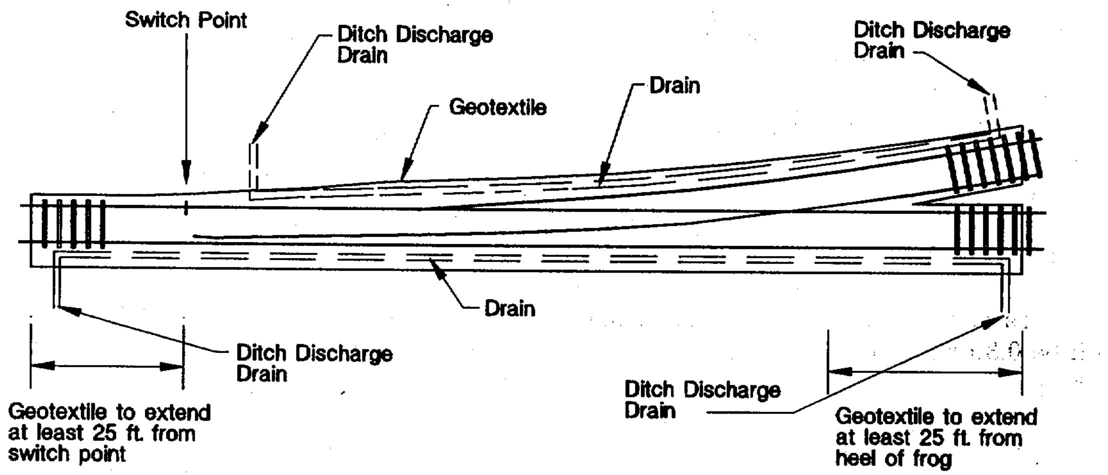
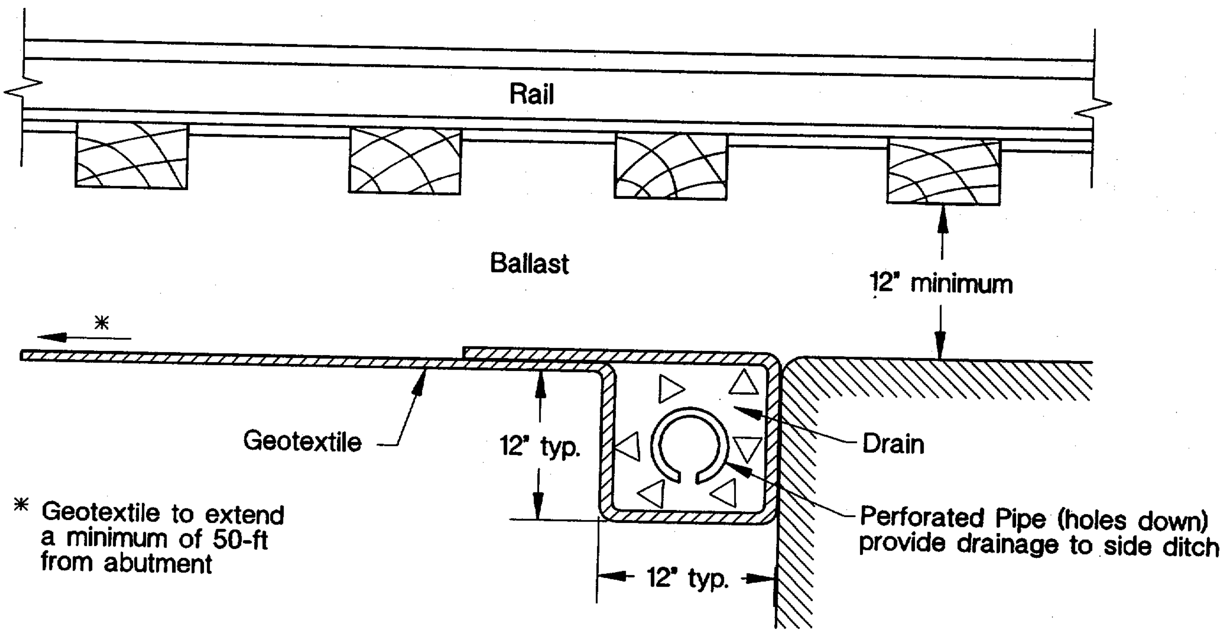


Figure 6-16. Geotextile installation under a turnout.



Profile View

Figure 6-17. Geotextile installation at a bridge abutment.

6-9. Ballast.

a. Purpose. Ballast performs four primary functions:

(1) Distributes wheel loads at reduced pressure to the subgrade.

(2) Restrains the track laterally and longitudinally.

(3) Helps maintain track surface.

(4) Allows track structure to drain.

b. Material Ape.

(1) As ballast depends on high friction and interlock to be effective in restraining track and must also withstand large loads, ballast must consist of a hard angular crushed rock or crushed slag.

(2) Common rock materials suitable for ballast are granites, traprocks, quartzites, dolomites,

and hard limestones. As limestones degrade, they end to produce fine particles which cement together, and are thus not the best ballast choice if other hard rock material is economically available. Crushed slag can also vary greatly in quality and suitability for good ballast.

c. Gradation.

(1) Recommended AREA ballast gradations are given in table 6-3. For main running tracks, sizes 3, 4A, and 4 will be used, with 4A or 4 ,referred. For loading tracks in terminal areas, size 5 may be used to facilitate easier walking along the cars during loading and unloading operations, but a larger size is preferred for long term track maintenance. AREA ballast gradations 3 and 4 are identical to ASTM C33 gradations 3 and 4, respectively. ASTM C33 gradation 56 is lose to AREA no. 5.

(2) For smaller projects, where less than 200 tons of ballast is needed, and where the nearest suppliers do not stock AREA gradations, the following highway gradations may be substituted: CA3 for AREA 3, CA5 for AREA 4 or 4A, and CA7 for AREA 5.

d. Depth.

(1) Appropriate ballast depth will be determined by structural analysis using the computer programs specified in paragraph 6-2. The manual method described in paragraph 6-3 may also be used but is not preferred.

(2) In all cases, the minimum depth of ballast from the bottom of the tie to the subgrade will be 8 in. In most cases, however, main running tracks will require more.

e. Cross Section. Standard ballast shoulder widths and side slopes are shown in figures 6-5 through 6-11. In finished or resurfaced track, the ;p of ballast may be up to 1 inch below the top of he tie, but never above the top.

6-10. Sub-Ballast.

a. Purpose. Sub-ballast is a layer of material between the top ballast and subgrade with a gradation finer than the top ballast and coarser than the subgrade. Often cheaper than top ballast, it can be used to reduce total ballast cost or to provide a filter layer between the top ballast and a fine-grained subgrade. A sub-ballast layer is shown in figures 6-6, 6-8, 6-9, and 6-11.

b. Application. A sub-ballast layer is recommended for most new construction. In addition to providing a filter to keep subgrade particles from working up into and fouling the ballast, it provides a good mat to distribute loads from the ballast and prevents ballast particles from being pushed into the subgrade. A sub-ballast layer is required whenever:

(1) The subgrade contains 85% or more (by weight) of silt and clay sized particles, or:

(2) The subgrade material has a liquid limit greater than 50 and a plasticity index greater than 20.

b. Material. Sub-ballast should be a hard, angular, non-cementing material, primarily of sand sized particles.

c. Gradation.

(1) To function well as a filter layer, the sub-ballast particles should range in size from the smallest ballast particles to the largest subgrade particles.

Table 6-3. Recommended Ballast Gradations.

Size No.	Nominal Size Square Opening (in.)	Amounts Finer Than Each Sieve (Square Opening) Percent by Weight							
		2-1/2in.	2 in.	1-1/2in.	1 in.	3/4 in	1/2 in.	3/8 in.	No. 4
3	2to 1	100	95-100	35-70	0-15		0-5		
4A	2 to 3/4	100	90-100	60-90	10-35	0-10		0-3	
4	1-1/2 to 3/4		100	90-100	20-55	0-15		0-5	
5	1 to 3/8			100	90-100	40-75	15-35	0-15	0-5

(2) Over a clay or silty clay, with greater than 85% passing the no. 200 seive, the following gradation is recommended:

Seive Size	1/2"	3/8"	#4	#10	#20	#40	#100	#200
Percent Passing	100	90	80	70	50	40	20	10.

This gradation can be approximated by specifying the middle to finer side of the range for ASTM D 1241 gradation D.

(3) Over a subgrade with more than 15% larger than no. 200, such as the middle to coarser side of the range for ASTM D 1241 gradation D.

d. Depth.

(1) During' structural analysis, the subballast layer is considered as part of the total ballast depth.

(2) A sub-ballast layer may comprise up to 40% of the total ballast depth on main running tracks and up to 50% on auxiliary and terminal tracks.

(3) When used, the minimum sub-ballast thickness will be 4 inches with a minimum total ballast depth of 10 inches.

6-11. Ties and Tie Spacing.

a. Material.

(1) Ties will be made of wood and will meet the requirements in the AREA manual. The recommended species of wood for cross ties are:

Hardwoods	*Softwoods*
Ash	Douglas Fir
Beech	Pine
Hickory	Spruce
Red Oak'	
White Oak	

(2) Strictly defined,. hardwood and softwood refer to a type of tree and not the harness or density of the wood. However, the hardwoods listed above are denser and generally more durable than the listed softwoods and thus usually more desirable for ties. While softwoods are sometimes preferred on open deck bridges to help absorb impact, they are not recommended for use in turnouts or in sharp curves (over 8 degrees) where the better spike-holding ability of the denser woods is needed.

(3) Hardwood ties are often sold in species groups such as mixed hardwoods or oak. The mixed hardwoods may comprise, for example, 40% oak and 60% assorted hardwoods, including gum. Gum is not a preferred species, but is commonly used. The oak group is usually a mix of red and white oak and typically costs more than the mixed hardwoods.

(4) For track with annual traffic volumes of 5 MGT or less, as is common at military installations, ties are more likely to fail from decay rather than mechanical wear or loss of spike-holding ability. In such cases, tie selection should lean toward available species which readily accept deeply penetrating preservative treatment. Information' from the engineering department of the serving commercial carrier, from regional tie suppliers, and from local experience should help in selecting the most appropriate ties.

b. Cross Section and Length.

(1) The two common cross sectional sizes for track ties are 7 inches thick by 9 inches wide or 6 inches thick by 8 inches wide.

(2) 7x9 ties are recommended for areas with higher traffic volumes and wheel loads as well as in turnouts and in road crossings.

(3) Track ties are commonly produced in 8.5 or 9-foot lengths. The 8.5-foot length will be used when most conveniently available..

(4) 'Ties for turnouts vary from 9 to 17 feet long and will be ordered as indicated in table 6-5.

c. Treatment.

(1) All wood ties will be pressure treated with preservative as specified below.

(2) The preferred preservative for ties is a creosote-coal tar solution (60/40) as specified in AWPA standard P2.

(3). For ties used west of the Mississippi River, where attacked by organisms such as fungi and termites is generally not as severe, a creosote petroleum solution (50/50) as specified by AWPA standard P3- may be used.

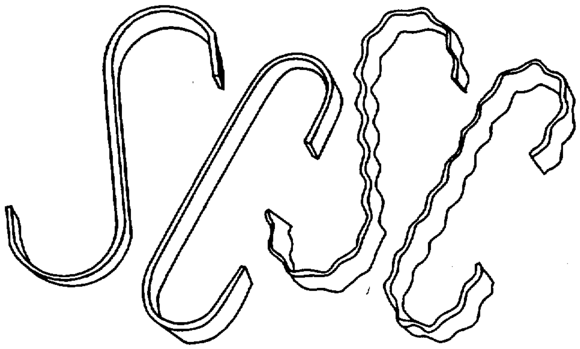
d. Anti-splitting Devices. To reduce the tendency of wood to split, anti-splitting devices are often applied. to the ends of ties. Anti-splitting devices are recommended for turnout ties but may be specified for standard track ties. Of the two general types, as shown in figure 6-18, the nail plates are more effective and thus preferred.

e. Preboring. Once common practice, the preboring of spike holes is no longer recommended.

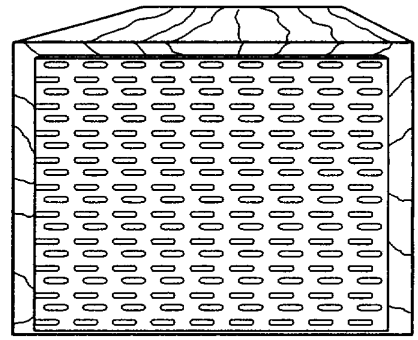
f. Tie Spacing. The center-to-center distance between adjacent ties will usually range from 19.5 to 22 inches, with a minimum allowable of 18 inches and. a maximum of 24. For auxiliary and loading tracks, a 21 to 23-inch spacing will often suffice. Tie spacing will be specified after a structural analysis has been performed.

g. Concrete and Other Non-Standard Ties.

(1) Concrete ties are used by some commercial railroads, particularly on lines with the heaviest traffic volumes and in areas with numerous curves. Where used, concrete ties are in track with welded rail and solidly supported with deep ballast sections. Concrete



a. S and C Irons



b. Nail Plate

Figure 6-18. Anti-Splitting Devices for Tie Ends.

ties are usually not economical on lighter traffic lines, and are usually not suitable for use with jointed rail or in track of lighter construction. Also, concrete ties cannot be successfully mixed with wood ties. Thus, concrete ties are not recommended for general use in military track.

(2) The use of concrete ties for certain special applications may be cost effective. The economic benefit of these installations must be thoroughly investigated prior to the selection of concrete ties.

(3) Research and development continues on ties made with alternative materials and of hybrid construction. None have yet proven economical for routine, general purpose use.

6-12. Rail.

a. Section designation. Rail is rolled into different sizes (dimensions) and shapes commonly referred to as "weight" and "section." The weight of a rail is based on how much a rail weighs in lbs per yd of length. The section refers to the cross sectional shape of the rail.

b. Selection Criteria. Selection of a rail section will be done only after a structural analysis has been performed. Designers will determine structural requirements as well as cost and availability of rail sections before a final selection is made.

c. Recommended New Rail Sections.

(1) Weights and sections recommended for new rail purchases are: 115RE, 132RE, 133RE, and 136RE, with 115RE preferred. These are the standard sections recommended by the AREA and should be available for many years.

(2) Rail may be purchased in either 39 ft or 80 ft lengths. Rail 80 ft long has the advantage of reducing the number of joints to half that for 39 ft rail. For small purchases where the rail may be transported by truck 39 ft lengths may be more cost effective.

d. Relay (Secondhand) Rail.

(1) Secondhand rail which meets the specifications in table 6-4 either as is or after cropping off the ends, may be used for rehabilitation or new construction. Before selecting relay rail, the cost, condition, and availability of matching joint bars and tie plates must be investigated.

(2) Recommended relay rail sections are: 100ARA-B, 112RE, 115RE, 130RE, 132RE, 133RE, and 136RE.

(3) Relay rail should be selected to limit the number of different rail weights and sections within the track network. For a given weight, the section and joint drilling pattern (bolt hole size and spacing) should also be consistent.

(4) Due to the varying market for relay rail it may be beneficial to allow the contractor an option to provide an acceptable rail section. Selection should be limited to those sections which are sufficiently plentiful to supply future maintenance purchase requirements: rail, joint bars, frogs and other turnout parts.

e. Lightweight Rail.

(1) Lightweight rail weighs less than 90 lbs per yd. These weights are no longer manufactured and are only available as secondhand.

(2) For main running tracks, rail weights less than 90 lbs per yd will not be used. Rail weighing 75 lbs per yd to 85 lbs per yd may be adequate for terminal and auxiliary tracks with light use, depending upon support conditions. A structural evaluation is necessary to determine the adequacy of these rail weights. Rail not

Table 6-4. Dimension and Surface Specifications for Relay (Secondhand) Rail.

Length	- Standard 33 ft or 39 ft lengths. - 90% of lot 33 ft or longer. - Not more than 10% of lot between 27 ft and 33 ft. - No rail shorter than 27 ft.
Vertical Wear	- Average top wear 1/8 in. or less with maximum at any one location of 5/32 in.
Side Wear	- Maximum of 1/8 in., with wear on one side only.
Lip or Overflow	- Maximum of 1/16 in.
Engine Burns	- Maximum of 1/2 in. diameter (or 1/4 in. wide by 1/2 in. long) and 1/32 in. deep. - Maximum of six engine burns per rail. - Engine burns on no more than 25% of the lot.
End Batter and Chipping	- Maximum of 1/8 in. when measured 1/2 in. from the rail end with an 18 in. straightedge.
Running Surface Damage	- Maximum of 1/4 in. wide by 1/2 in. long and 1/32 in. deep. - Flat spots are not permitted on the rail head.
Defects Not Permitted	- Bolt hole cracks or breaks, broken base, crushed head, detail or engine burn fractures, head-web separation, piping, horizontal or vertical split head, torch cuts or flame gouges, compound or transverse fissures, pitting.
Condition and Appearance	Rail must be: - Free from obvious defects. - Clean in appearance. - Straight in line and surface and free from kinks. - Free from base defects such as plate wear, spike notches, pitting, and flame-gouging.

adequate to support the desired wheel loads should be replaced.

f. Continuous Welded Rail (CWR).

(1) Continuous welded rail (CWR) is strings of standard rail welded together either in a rail plant or by field welding after installation. CWR is commonly used on commercial railroads and is beneficial in reducing maintenance costs due to rail joints.

(2) CWR is not recommended for general use on military track as it requires a larger ballast section to provide sufficient track restraint, needs more rail anchors to restrain longitudinal rail expansion, is more subject to buckling in hotter weather and pull-aparts during colder weather, and has a higher initial installation cost. If conveniently available, short strings (less than 200 feet) may be appropriate for wide road crossings or track in paved areas.

g. Field Welds.

(1) It is recommended that rail through road crossings and for 20 ft on either side of crossings be welded to eliminate joints in these areas. Likewise, field welding should be considered for rail placed in confined loading areas, adjacent to warehouse loading docks, and in other areas where maintenance access to rail joints would be difficult.

(2) Rail welding may only be accomplished with special thermite welding kits designed for this purpose and by people with the necessary training and experience in welding rail. Where many welds are to be done, some specialized contractors have truck-mounted electric welding units designed for this purpose.

h. Salvaging Rail. During track reconstruction the existing rail and other track materials can often be salvaged for use at other locations on the installation, stockpiled for future construction projects or sold on the open market as used material. Lightweight rail, defective rail, and-other track materials not suitable for use in track reconstruction on the installation or for resale on the open market should be disposed of as scrap or reroll material.

6-13. Other Track Material.

a. Definition. Tie plates, joint bars, bolts, spikes and other miscellaneous hardware used in track construction are commonly referred to as other track materials (OTM).

b. Tie Plates.

(1) Tie plates vary in length and width. Most sizes are suitable, as long as the spike hole punching (or distance between the shoulders-for double shoulder plates) matches the width of the rail base. For double shoulder tie plates, the distance between the shoulders will be at most 1/8 inch larger than the rail base width. On single shoulder plates, the spike holes on the gage side (opposite the shoulder) must keep the inside face of the spike within 1/8 inch of the rail base when the opposite edge of the base is against the shoulder. (see fig 6-19(a) and (b).)

(2) Either single or double shoulder tie plates can be used.

(3) Within a given length of track, tie plates of different lengths and widths may be used, and single shoulder plates may be mixed with double shoulder plates. However, plates with different cants (i.e. those with level rail seats and those with a 1:40 slope) will not be mixed. Tie plates with a 1:40 cant are preferred.

(4) Secondhand plates which are not bent, have not lost much material due to corrosion, and otherwise. meet the above requirements, are acceptable.

c. Spikes. On tangent track and. on curves up to 4 degrees, one spike on the gage and field side of each rail will be used (a total of 4 spikes in each tie). On curves greater than 4 degrees, one spike on the field side and two spikes on the gage side of each rail will be used (a total-of 6 spikes in each tie).

d. Rail Joints and Joint Bars.

(1) Either four-hole (24-inch) or six-hole 36-inch) joint bars may be used for rail joints.

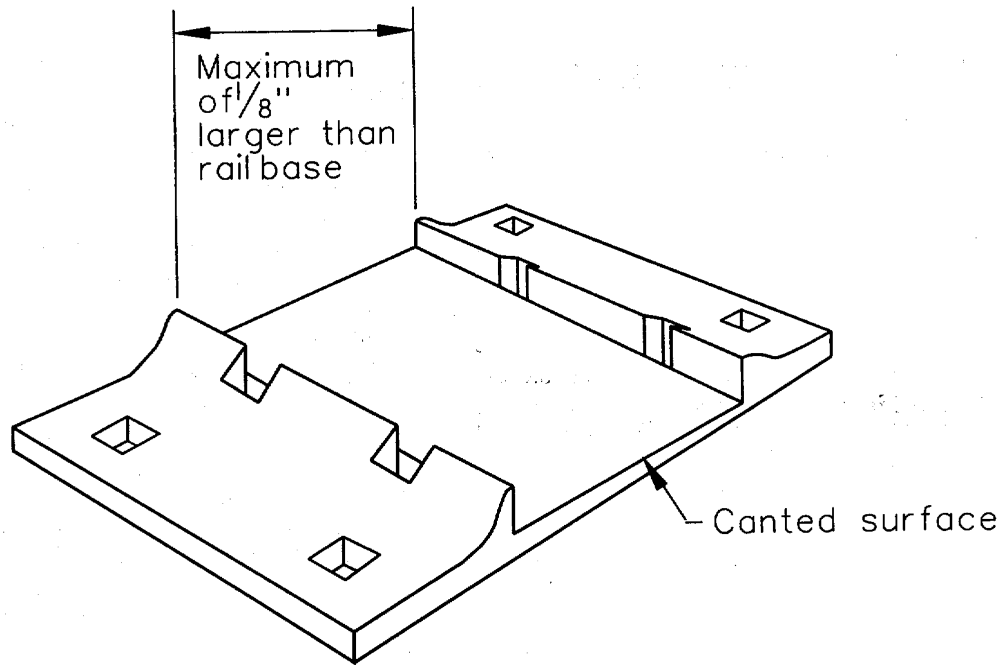
(2) Standard and compromise joint bars will be properly factory designed and constructed and will be of the size, shape and punching pattern to fit the rail being joined. New joint bars will meet “Specifications for High Carbon Steel Joint Bars" or "Specifications for Quenched Carbon Steel Joint Bars and Forged Compromise Joint Bars" in chapter 4, part 2 of the AREA Manual and joint bar assemblies in chapter 4, part 1 of the AREA manual. Compromise joints will be specified as indicated in AREA Plan 700B.

(3) Secondhand joint bars may be used on secondhand rail if not bent, cracked, excessively corroded, or otherwise defective. Secondhand joint bars will not be used on new rail.

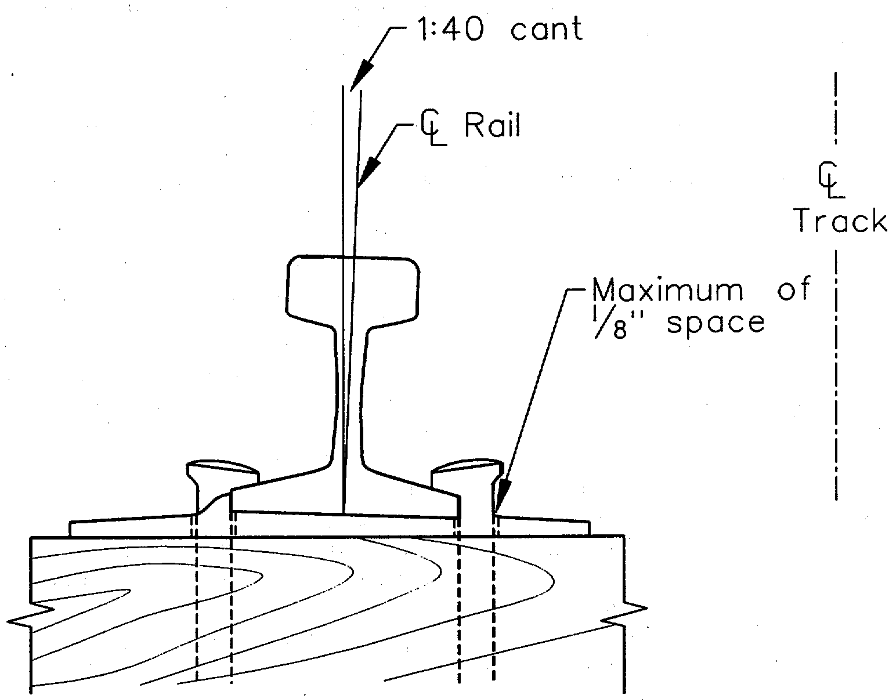
(4) Insulated joints required to isolate signal currents. for road crossing warning devices may be either the field-applied type or prefabricated (glued) type. Special insulated tie plates are also required.

(5) It is recommended that rail joints be welded where located in road crossings, paved areas, or at any location where access to the joint is restricted.

e. Track Bolts, Nuts, and Spring Washers.



A. Double shoulder tie plate with 1:40 cant



B. Single shoulder tie plate with 1:40 cant

Figure 6-19. Tie Plates.

(1) Track bolts, nuts, and spring washers will conform to the specifications in chapter 4, parts 1 and 2, of the AREA manual.

(2) Common bolt diameters for different rail weights are as follows:

Bolt Diameter, in.	*Rail Weights, lbs per yd*
3/4	60to75
7/	70 to 90
1	90 to 130
PIA	131 to 140

f. Rail Anchors.

(1) Rail anchors restrain longitudinal rail movement and should be used on main running tracks in the quantity and arrangement diagramed in figure 6-20, as a minimum. Additional anchors may be required on track with grades steeper than 0.5%, and where combinations of traffic volume, speed, and curvature indicate a need.

(2) When anchors are used, each tie which is anchored will have 4 anchors applied per tie (box anchored), as shown in figure 6-20.

(3) Either type of anchor, spring or drive-on (shown in figure 621), may be used. Drive-on anchors have the advantage of being easier to apply and remove manually, and do not require a special anchor wrench, as do spring anchors. It is possible, though, to over-drive a drive-on anchor, causing it to lose its ability to tightly grip the rail base.

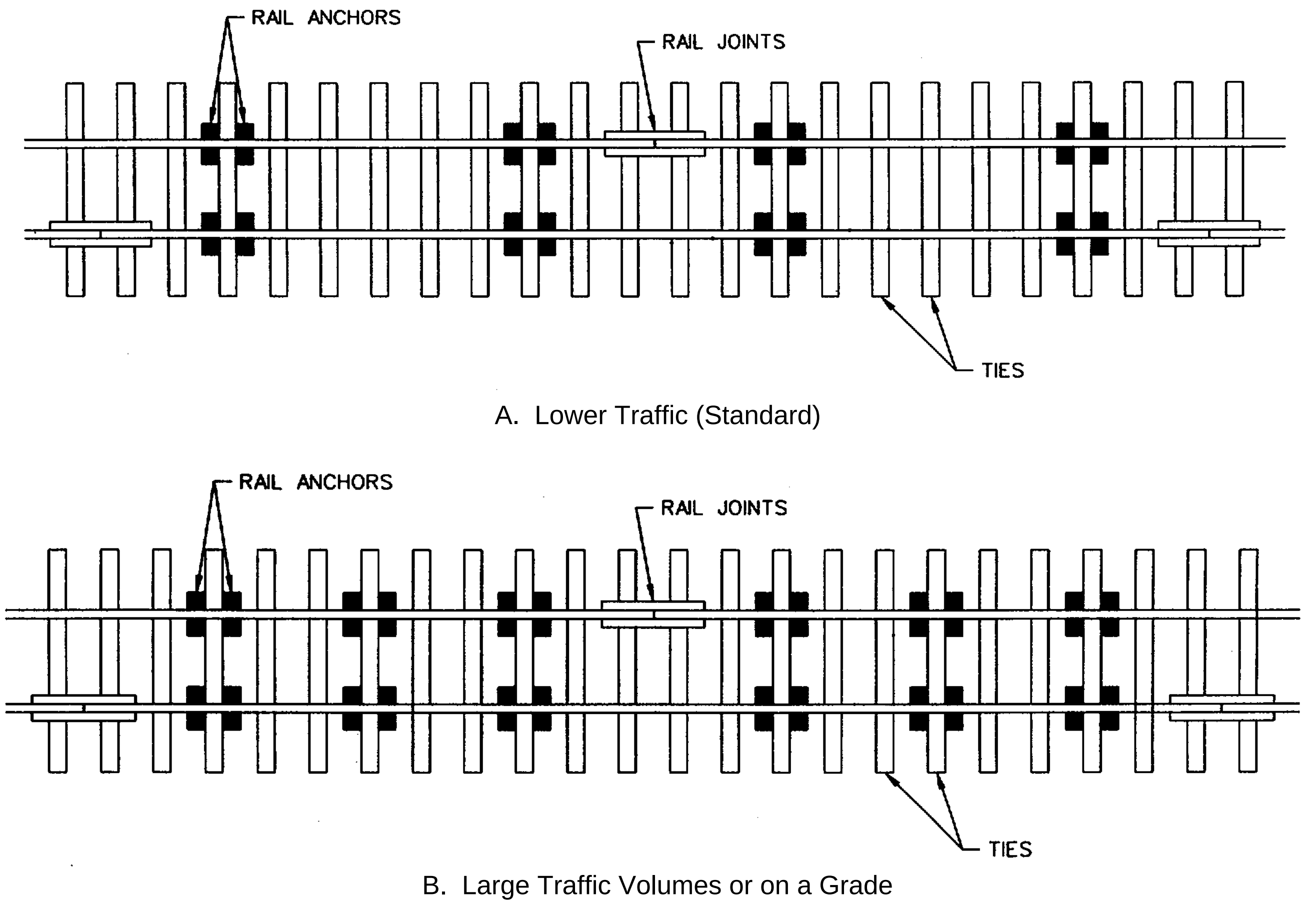


Figure 6-20. Recommended Minimum Rail Anchor Application.

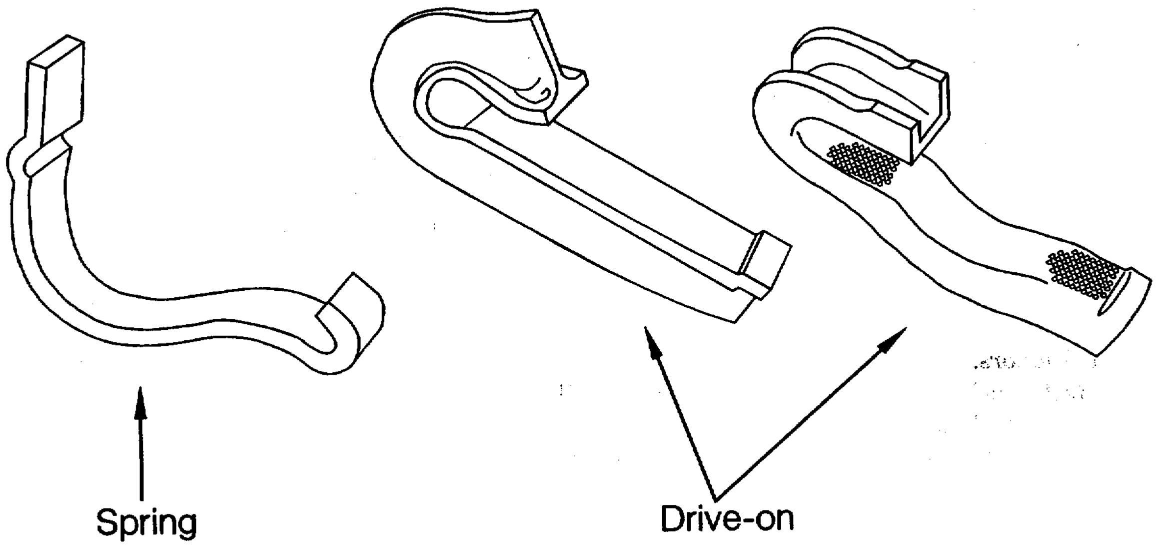


Figure 6-21. Rail Anchors.

(4) Rail anchors will not be used across deck bridges. Instead, for two rail lengths off end of the bridge, every third tie should be anchored. A similar arrangement should be at rail crossings, as shown in figure 6-22. Rail anchors should be applied at the normal designated pattern across ballast deck bridges.

g. Gage Rods.

(1) Gage rods are sometimes specified for sharp curves (over 8 degrees) where difficult holding gage is anticipated. Where used on sharp curves, two to four rods should be installed rail length.

(2) The general use of gage rods is not encouraged and should be reserved for special or unusual cases.

6-14. Turnouts and Crossovers.

a. Description. Turnouts are designed to divert trains from one track to another. Two turn form a crossover when used together to allow passage of trains between parallel tracks The general arrangement of turnouts and crossovers is shown in figure 6-23. The main parts of a turnout are shown in figure 6-24. For additional switch detail see AREA Plans 190, 220, and 221.

b. Design and Selection.

(1) The main design decisions for turnouts are the direction in which the turnout will diverge (as shown in fig 6-23), and the angle of the frog (or frog number), which determines how sharply the turnout diverges (and also designates the size of the turnout). These and other geometric aspects are covered in chapter 7. Recommended choice for different designs and materials of specific turnout parts are covered below.

(2) Once turnout geometry has been determined from chapter 7, the designer will specify the desired turnout by selecting: a switch, a frog, and guard rails, if needed, from the appropriate AREA plans; the turnout (or crossover) tie set from table 6-5; and the amount of rail needed to complete the turnout (connect the switch and frog) from AREA Plan 910 or 911. Guidance on the selection of these items and other turnout hardware is given below.

(3) All materials used within the limits of a turnout will be factory designed and constructed, per of the proper type and size, and not be flame cut or otherwise altered in the field.

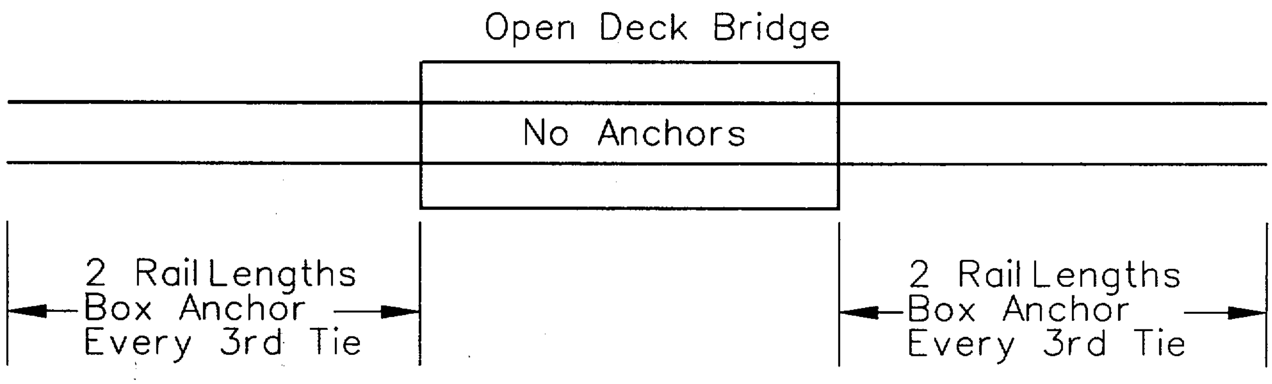
c. Switches and Switch Points.

(1) The standard switch for use on military track is the 16’6" switch with graduated risers, as shown in AREA Plan 112. The detailed specification for this switch is given in the notes in the upper right corner of plan. In most cases, the specification will be for a 112E or 112F (noninsulated hand throw-rigid braces), or if adjustable braces are desired, specification 112A or 112B-omit insulation (Note 2(e)), if the switch is not within a signal circuit (as near crossings with warning lights or gates). Shorter or longer switches may be used, as needed, but switches shorter than 15 feet are not recommended.

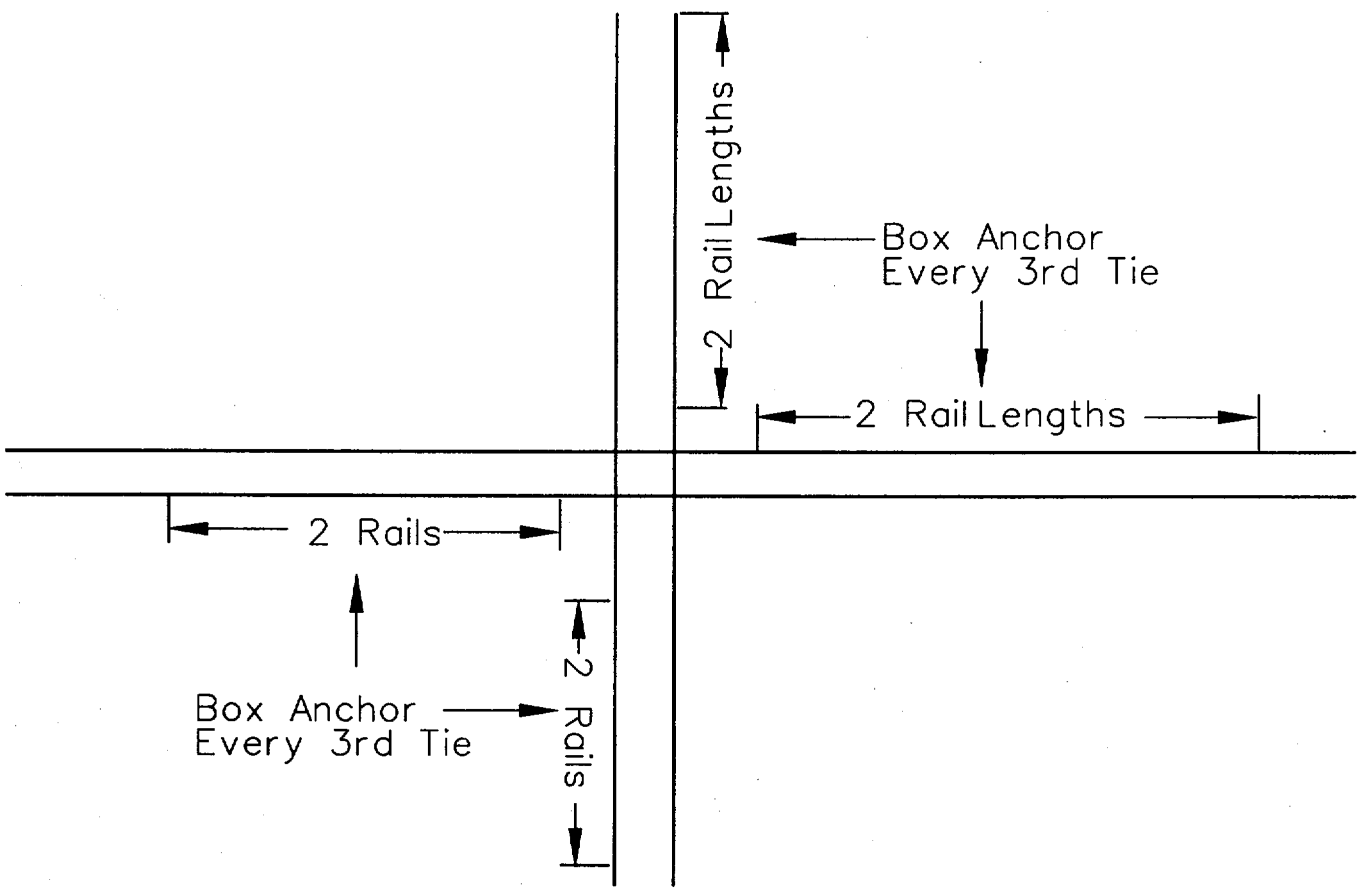
(2) In locations where traffic conditions may cause excessive wear on the tapered ends of the switch point, the use of alloyed steel (or hardened) switch points is recommended (AREA Plan 220).

(3) The use of spring switches is not recommended on Army and Air Force track.

d. Switch Clips. Either the adjustable side jaw clip or the adjustable transit clip, as shown at the top of AREA Plan 222, are suitable. The slanted row of holes in the clip provides adjustment in switch rod length ranging



A. Anchoring at Open Deck Bridges



B. Anchoring at Rail Crossings

Figure 6-22. Rail Anchor Applications at Open Deck Bridges and Rail Crossings.

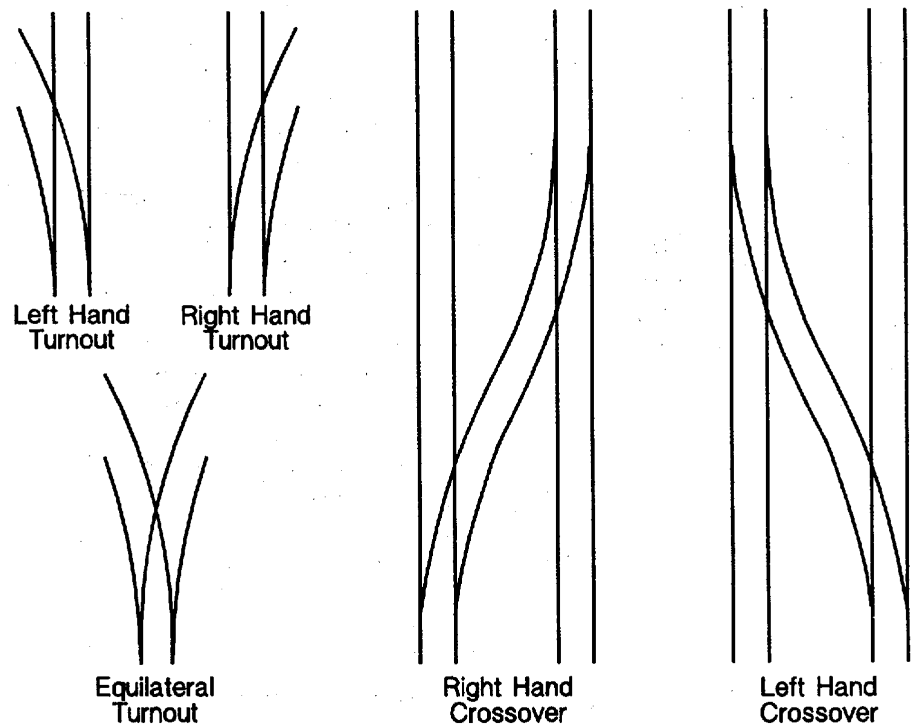


Figure 6-23. General Arrangement of Turnouts and Crossovers.

from 1/8 in. to 1/2 in., effected by moving the bolt from one hole to another.

e. Rail Braces. The rail braces which support the outside of the stock rails may be either the rigid or adjustable type. In most cases rigid braces will suffice, but where movements in both directions through the turnout may be frequent and under heavy loads, the adjustable braces are recommended.

f. Switch Stands and Lever Latches. Ground throw (low) switch stands are preferred, especially in terminal areas, while high stands may be preferred in more remote areas at the ends of passing sidings or where routes diverge. Many variations of stands are available and most are suitable, however, any stand selected should have a provision for the throw lever to lock or latch solidly in place. For switches in more remote areas, a switch point lock and/or lever lock may be desirable.

g. Frogs and Guard Rails.

(1) The solid manganese, self- guarded type frog, as shown in AREA Plans 641 and 691 (Section B-B), is preferred for the slower speed operations most common at military installations. Self-guarded frogs simplify turnout construction by not requiring separate guard rails opposite each side of the frog.

(2) Rail bound manganese (RBM) frogs, as shown in AREA Plan 600, may be used on heavy traffic lines where the traffic is approximately equal on both sides of the frog. This type of frog is most desirable for long turnouts (size 15 or above) since manganese steel is especially suited to the thin long points and requires comparatively little maintenance.

(3) Bolted rigid frogs, as shown in AREA Plan 320, can be used at any location on military installations, however, when new frogs are required, the two choices above are preferred.

(4) Spring rail frogs will not be used on Army and Air Force installations.

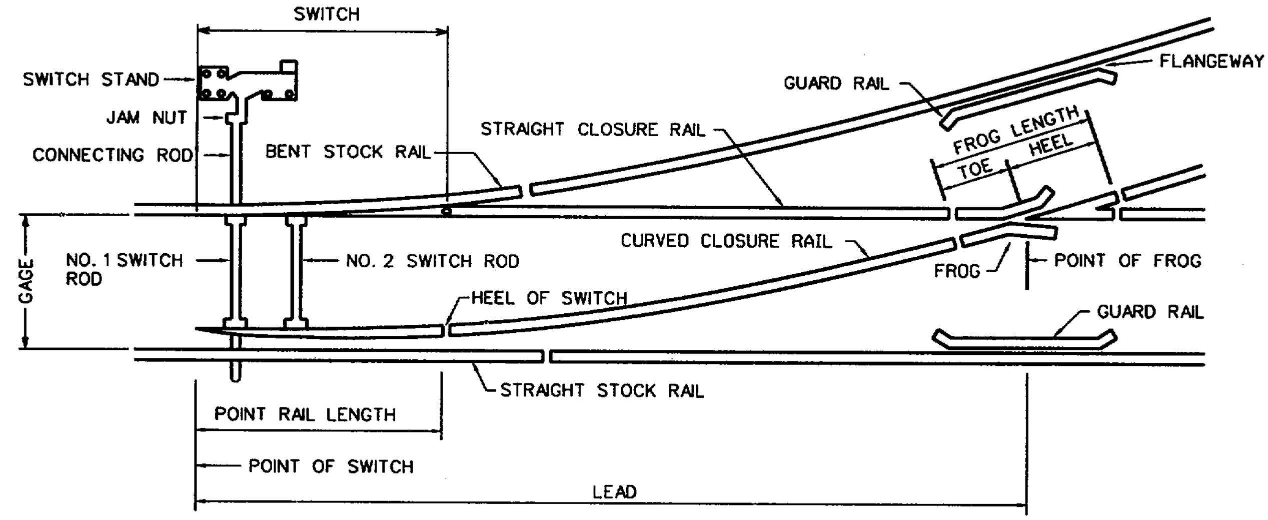
(5) Frogs are secured to ties with a set of hook plates, as shown in AREA Plan 241.

(6) When not using self-guarded frogs, guard rails will be specified to match the frog size, as listed in Note 2A of AREA Plan 502. Guard rails of the type in AREA Plans 504 or 510 may be used.

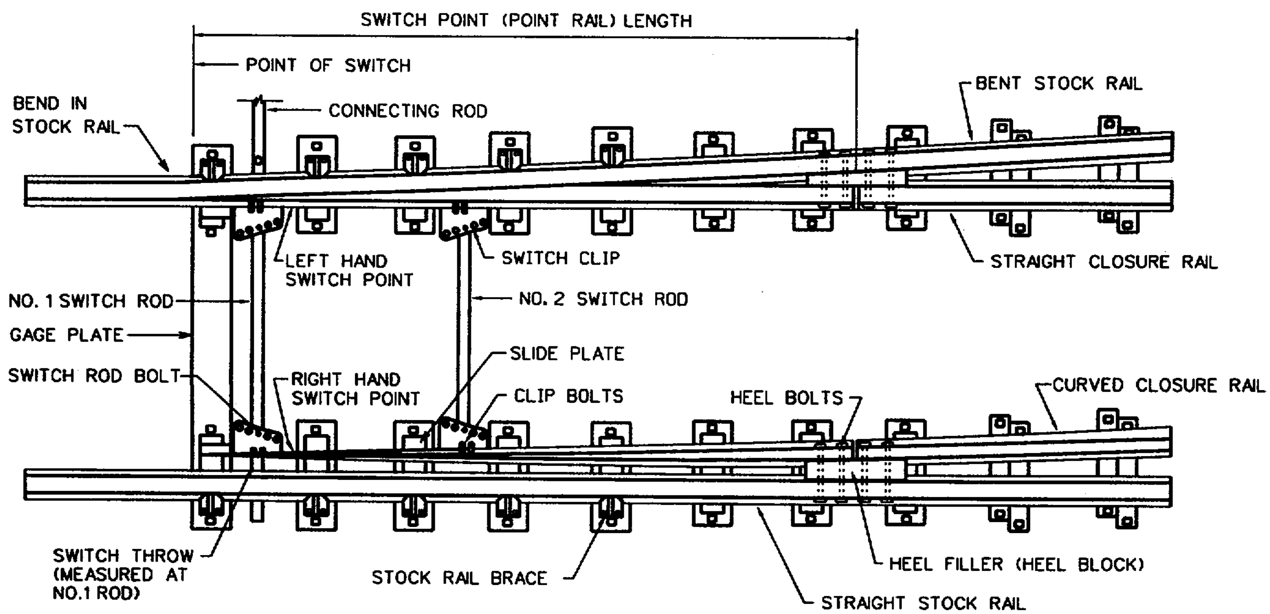
h. Stock Rails and Closure Rails.

(1) Enough rail to make up the straight and curved stock rails and closure rails must be supplied, as indicated in AREA Plan 910 or 911. This amount will approximately equal twice the actual lead (Column 4) plus the closure distances (Columns 5 and 6).

(2) All rail within the limits of a new or secondhand turnout will be of the same weight and



TURNOUT



SWITCH

Figure 6-24. Parts of a Turnout.

and section and should match the rails on the main and diverging tracks. Compromise joints are not permitted within the limits of a turnout.

(3) Where new switch points are specified with relay closure rail, a check must be made to assure that the top and gage side of the points and closure rails match at the heel joint.

(4) When turnouts will be rebuilt, and both new and relay rail will be available on the project, it is recommended that new rail be used to reconstruct the turnouts; this will avoid the potential problem of rail contour mismatch at the switch heel joints.

i. Switch lies.

(1) The make-up of switch tie sets and cross-over sets will be determined from table 6-5.

(2) 7" x 9" hardwood ties will be used for turnouts.

(3) Switch ties will meet the material and treatment specifications for standard track ties covered in section 6-11.

6-15. Road Crossings.

a. Design Steps.

(1) The main steps in designing a road crossing are determining the geometric layout, selecting the crossing surface, designing the drainage, designing the track section, and determining the appropriate protection. Crossing surfaces, drainage, track, and crossing protection are covered below. Some geometric design issues are covered in chapter 7.

b. Crossing Surfaces.

(1 Seven standard crossing types are listed in table 6-6, with cross sections and design details shown in figures 6-25 through 6-31.

(2) The following should be considered in selecting an appropriate road crossing surface:

(a) Vehicle traffic-volume, type and speed.

(b) Road use-road or street.

(c) Use by industrial traffic or special vehicles.

(d) Railroad traffic-volume, type and speed.

(e) Accident history for existing crossings where the crossing surface may have contributed to the accident.

(f) Cost-initial construction cost, replacement cost and maintenance cost.

(g) Expected service life.

(3) Type 1A crossings are intended for short-term use where vehicles must cross the track and where a permanent crossing is not required. A type 1A crossing is constructed with a minimum amount of effort in keeping with its function and life expectancy.

(4) In table 6-6, type 4A crossings are listed under light traffic densities for both low and high speeds. While not normally recommended for light duty roads, these crossings may be beneficial in industrial (warehouse) areas where the track must be encased in pavement.

Table 6-5. Switch lies for Standard Turnouts.

Frog #	Switch Point Length	Lead Distance	Number of Ties of Each Length								Total Ties
			9’	10’	11’	12’	13’	14’	15’	16’	
7	16-1/2	62’-1"	7	13	6	5	3	4	6	6	50
8	16-1/2	68’	7	13	6	6	4	5	7	6	54
9	16-1/2	72’-3.5"	7	13	7	7	6	5	8	6	59
10	16-1/2	78’-9"	7	15	8	7	6	6	7	8	64
11	22	91’-10.25"	10	17	9	8	8	6	8	8	74
12	22	96’-8"	10	17	10	9	8	7	9	9	79
14	22	107’-0.75"	10	17	13	10	9	8	11	11	89
15	30	126’-4.5"	15	21	15	11	10	9	11	12	104
16	30	131’-4"	15	21	15	12	12	11	10	12	108
18	30	140’-11.5"	15	24	17	12	11	11	13	14	117
20	30	151’-11.5"	15	26	19	12	12	11	15	16	125

Note: Each tie set includes 2 - 15’ ties for headblocks (which hold the switch stand)

Table 6-6. Recommended Crossing Surfaces.

	Recommended Crossing Surfaces					
Traffic Category:	**Light**		**Medium**		**Heavy**	
Vehicle Speed:	**< =35**	**>35**	**< =35**	**>35**	**< =35**	**>35**
Surface Type	1A 1B 2 3 4A +	1B 2 3 4A + 4B+	2 3 4A 4B	3 4A 4B 5	3 4A 4B 5	3 4A 4B 5

Surface Type Key:

1A	Gravel (Semi-Permanent)
1B	Gravel with Timber Headers
2	Timber
3	Asphalt
4A	Concrete: Cast-in-Place
4B	Concrete: Precast Panels/Systems
5	Elastomeric System

	Average Daily Traffic		**Design Hourly Volume**	
Traffic Category	**Road (Open Area)**	**Street (Built-Up Area)**	**Road (Open Area)**	**Street (Built-Up Area)**
Light	< 1000	< 2000	< 150	< 250
Medium	1000 - 5000	2000 - 8000	150 - 700	250- 1000
Heavy	> 5000	> 8000	> 700	> 1000

\+ May be used in warehouse areas for track in pavement.

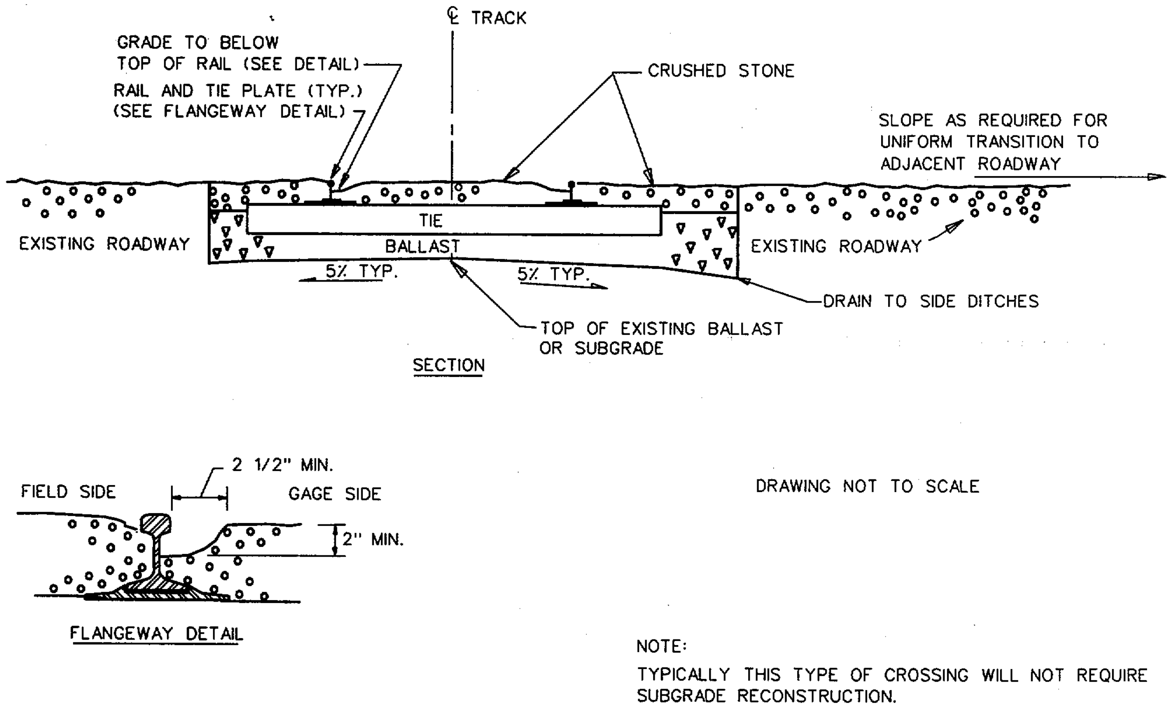


Figure 6-25. Typical Type 1A Gravel Crossing.

(5) Type 4B crossings should be constructed of reinforced concrete having a minimum 28-day compressive strength of 5,000 psi.

c. Drainage. All crossings, for all surface types require a subdrainage system similar to that shown in figures 6-32 and 6-33. Geotextile surrounding the pipe and filter is optional, but recommended in fine-particle soils where clogging of the filter may occur.

d. Track Construction.

(1) When crossings are built or rebuilt, all the ties in the crossing itself and for at least 20 ft beyond each end of the crossing should be replaced. It is recommended that wood ties use in road crossings be 7" x 9" in cross section. When prefabricated road crossings are installed, tie length and spacing should conform with the installation requirements provided by the crossing manufacturer.

(2) For road crossings having heavy volumes of rail traffic and heavy vehicle traffic, it may be desirable to install tie pads beneath the tie plates in the crossing area, as shown in figure 6-34.

(3) In crossings on main running tracks, rail of 115 lbs per yd or greater is preferred.

(4) As bolted rail joints in road crossings are often a maintenance problem, it is recommended that all joints through the crossing and for 20 ft from either end of the crossing be welded. As an alternative, 80-foot rails are readily available and may be used to eliminate joints in the crossing area.

(5) If the track approaching the crossing is anchored, it is recommended that each tie in the crossing be box anchored and that the normal anchoring pattern be maintained throughout the remainder of the crossing area (20 feet off each end).

(6) Once the crossing surface is in place, the track will be covered, making maintenance difficult and costly, thus the track geometry (gage, surface and alignment) should be nearly perfect before placing the crossing surface. The ballast in and around all the ties should be well compacted to prevent settlement and movement of the crossing.

(7) Crossing flangeways should have a minimum width of 2.5 in. with a maximum width of 3 in. and be at least 2 in. deep.

e. Crossing Protection: Signs and Signals.

(1) *Specifications and Minimum Requirements*. Specifications for the basic design and rail appearance of crossing warning signs, pavement markings, and warning signals are given in Part 8 of the Manual of Uniform Traffic Control Devices (USDOT-FHWA). All road crossings will have, at minimum, the standard warning signs shown in the MUTCD. The need for additional signs, flashing lights, or gates, depends on

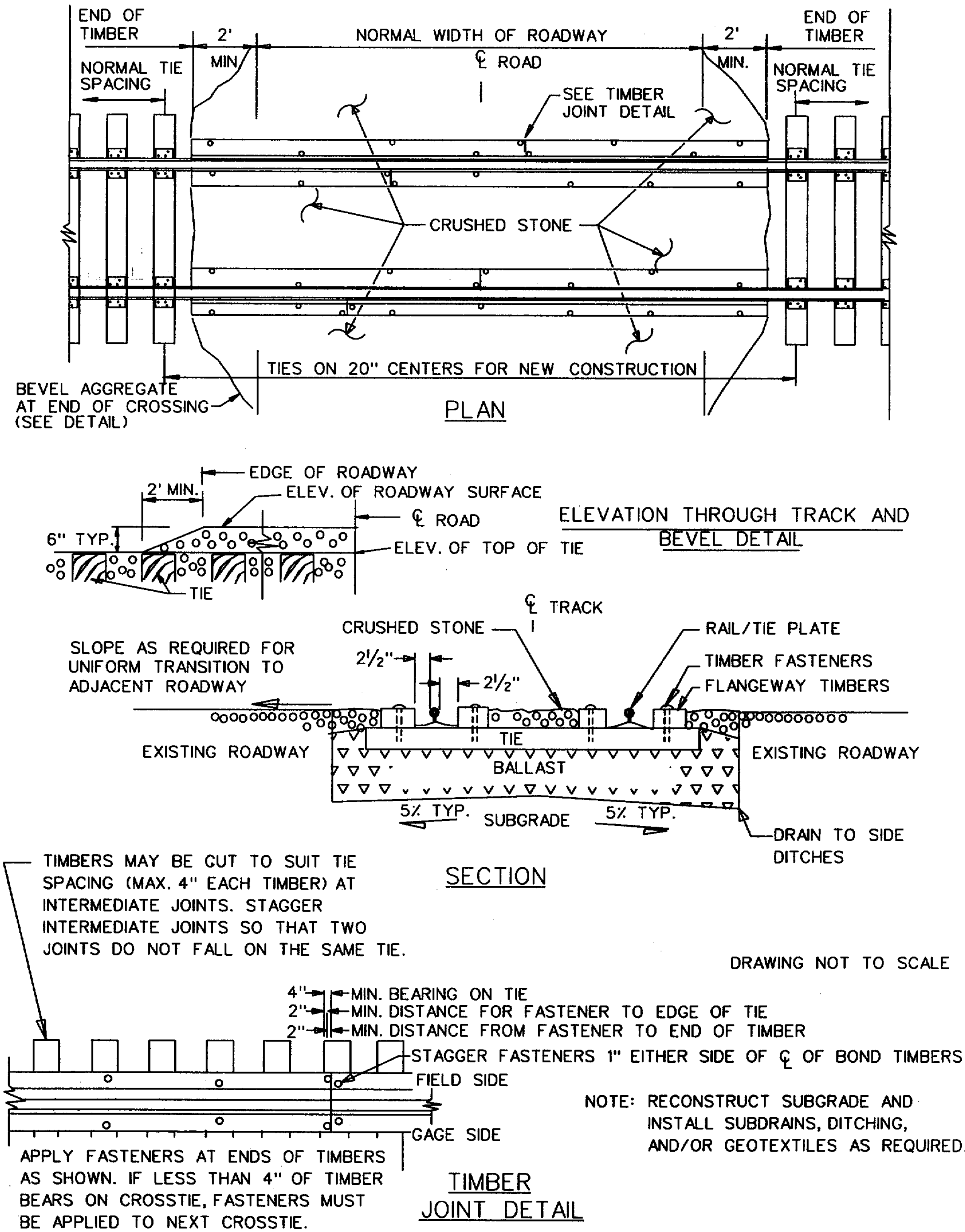


Figure 6-26. Typical Type 1B Gravel Crossing.

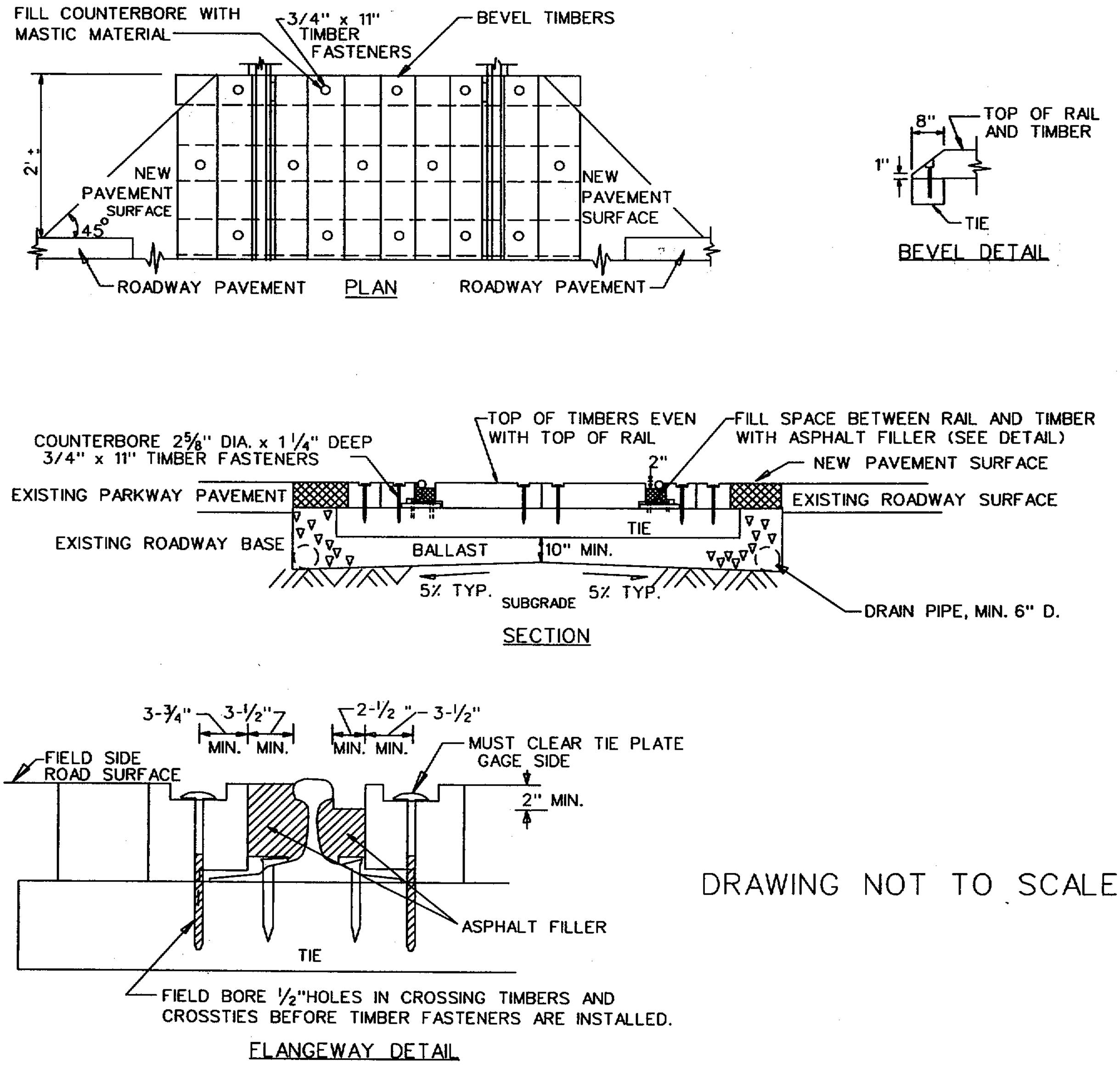


Figure 6-27. Typical Type 2 Timber Crossing.

crossing visibility, traffic character and volume, crossing geometry, and accident and incident history, as described below.

(2) *Visibility*. Clear visibility criteria for approaching and stopped vehicles is shown in figures 6-35 and 6-36, with distances A and B determined from table 6-7. A crossing is considered visually unobstructed if the triangular area defined by distances A and B is sufficiently clear that a motorist can see approaching trains anywhere within that field of view. Crossings which do not meet this clear visibility criteria may require additional protection.

(3) *Traffic Character and Volume.* Additional protection may be desirable at crossings which experience two or more train movements per day and the product of train movements and average daily vehicle traffic exceeds 3,000. This traffic threshold drops to 1,000 for crossings which are considered visually

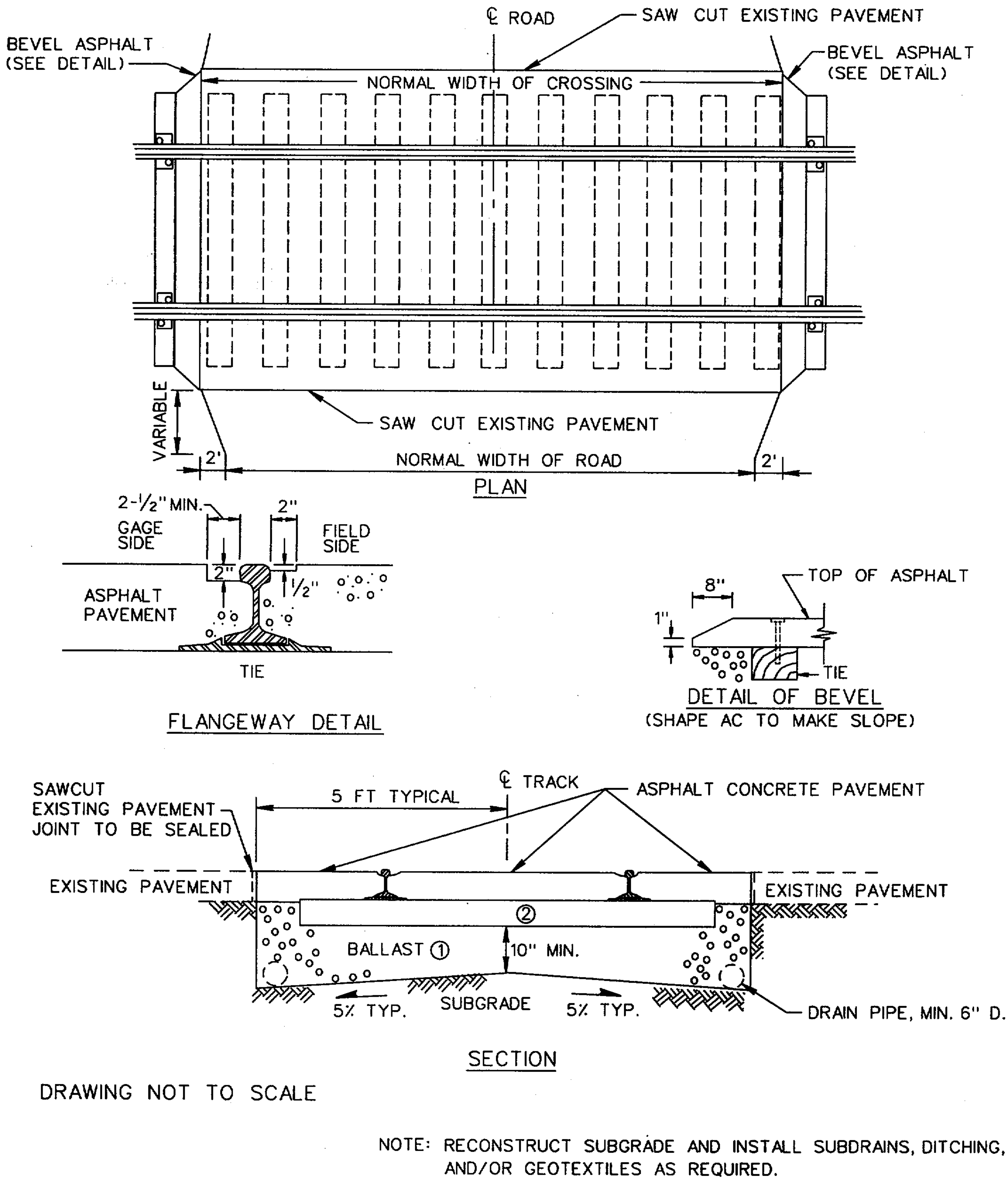


Figure 6-28. Typical Type 3 Asphalt Crossing.

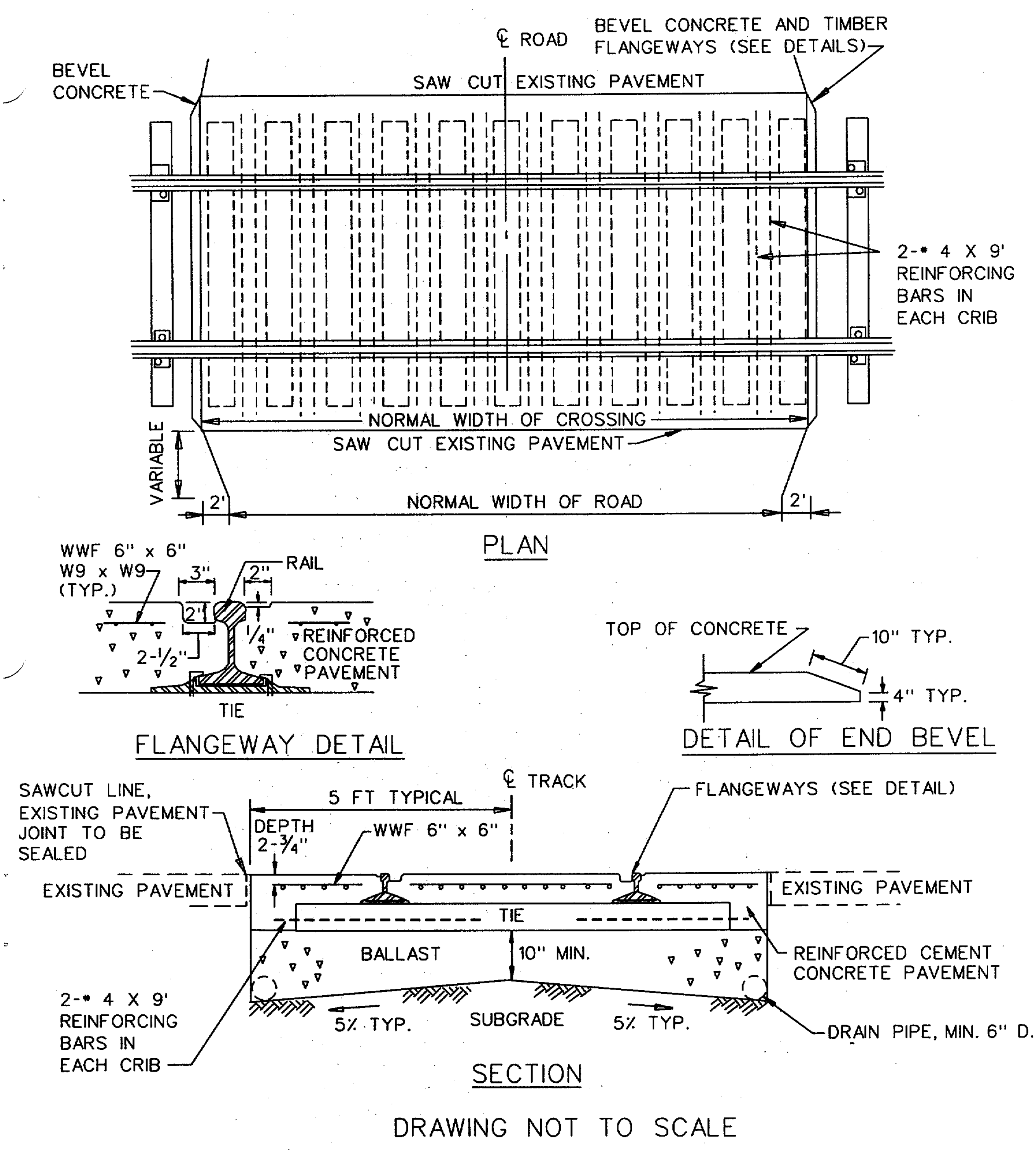


Figure 6-29. Typical Type 4A Cast-in-Place Concrete Crossing.

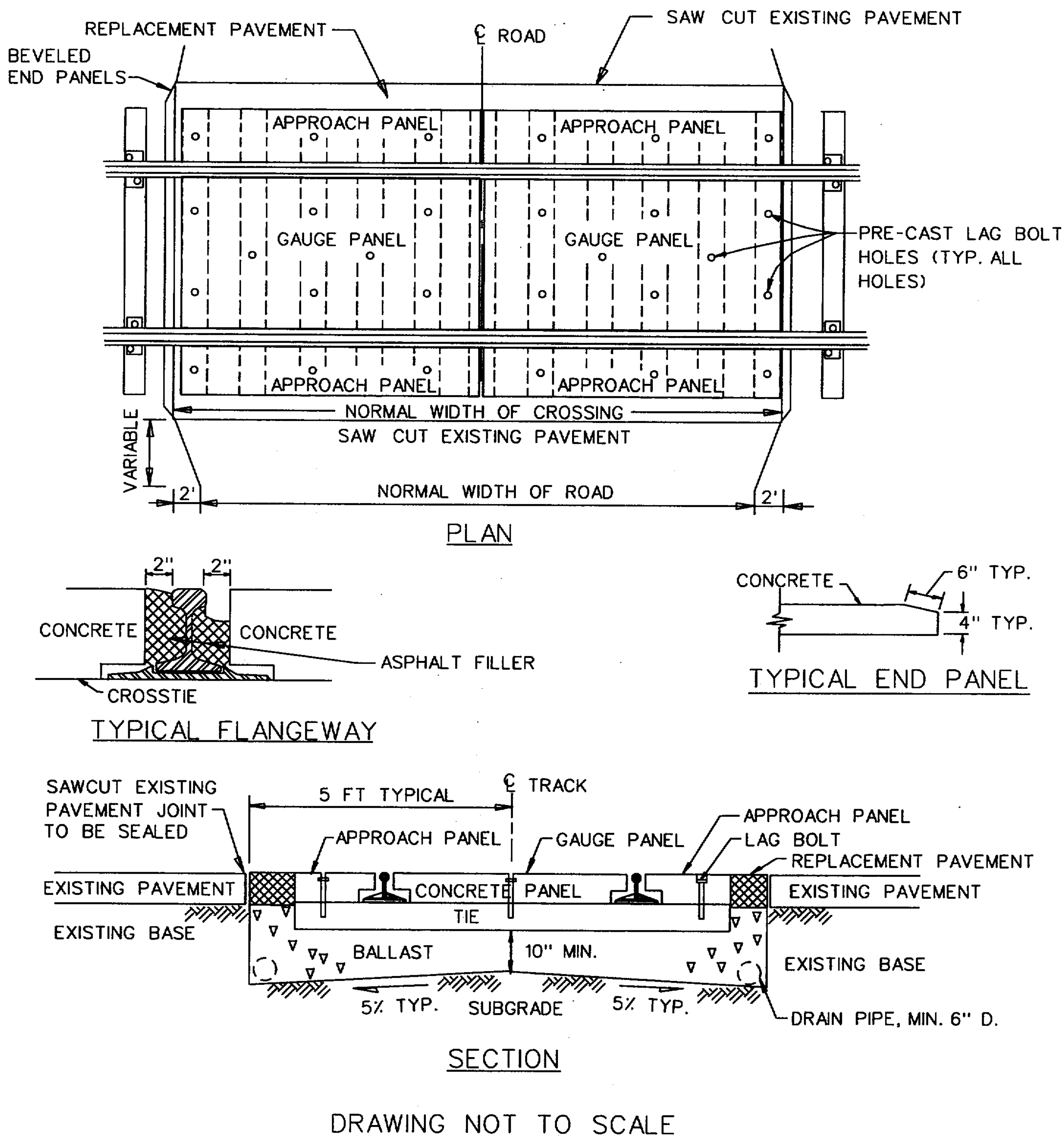
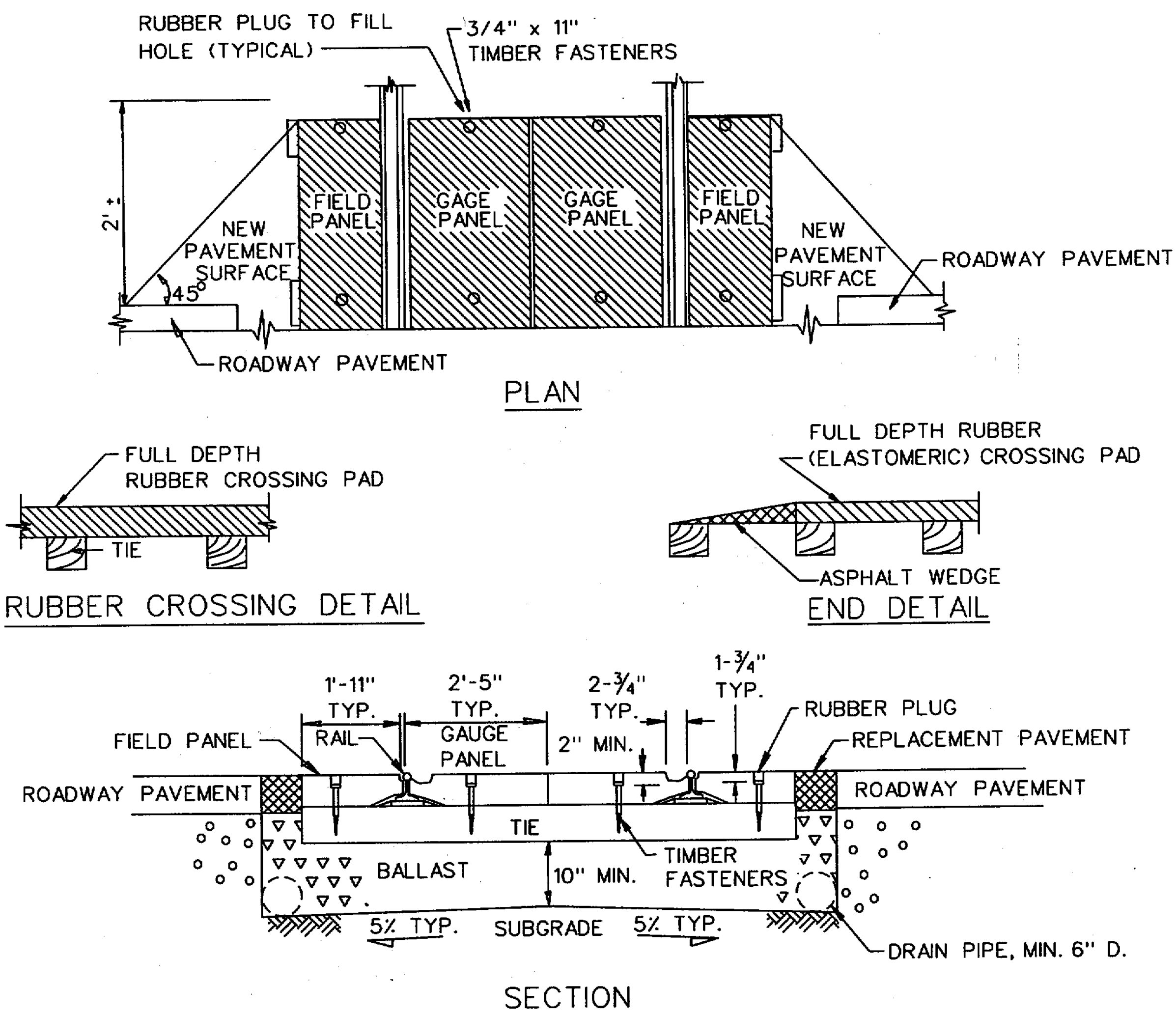


Figure 6-30. Typical Type 4B Prefabricated Concrete Crossing.



DRAWING NOT TO SCALE

Figure 6-31. Typical Type 5 Elastomeric (Rubber) Crossing.

obstructed, as defined above Flashing lights (or even gates) should be considered for crossings which experience several daily train movements and heavy truck traffic or frequent hazardous material traffic, especially if clear visibility criteria are not met.

(4) *Crossing Geometry*. Crossings with a road to track angle of less than 45 degrees, or where the road approaches the track at a steep grade may call for additional protection.

(5) *Accident and Incident History*. Crossings which have experienced at least one serious accident, some close-call incidents, and/or where incidents of motorists not obeying existing warnings are common, should at least receive consideration for flashing lights, or gates if flashing lights are already present.

6-16. Rail Crossings.

a. Recommended Types. Bolted rail crossings, as described in AREA Plan 700A, are recommended for use on military track. Tie layouts and plates for various angle crossings are given in AREA Plans 700F through 700J.

b. Anchoring Approaches. Where rail anchors are used on the tracks approaching rail crossings, every third tie should be box anchored (four anchors per tie) for at least two rail lengths in all directions from the crossings.

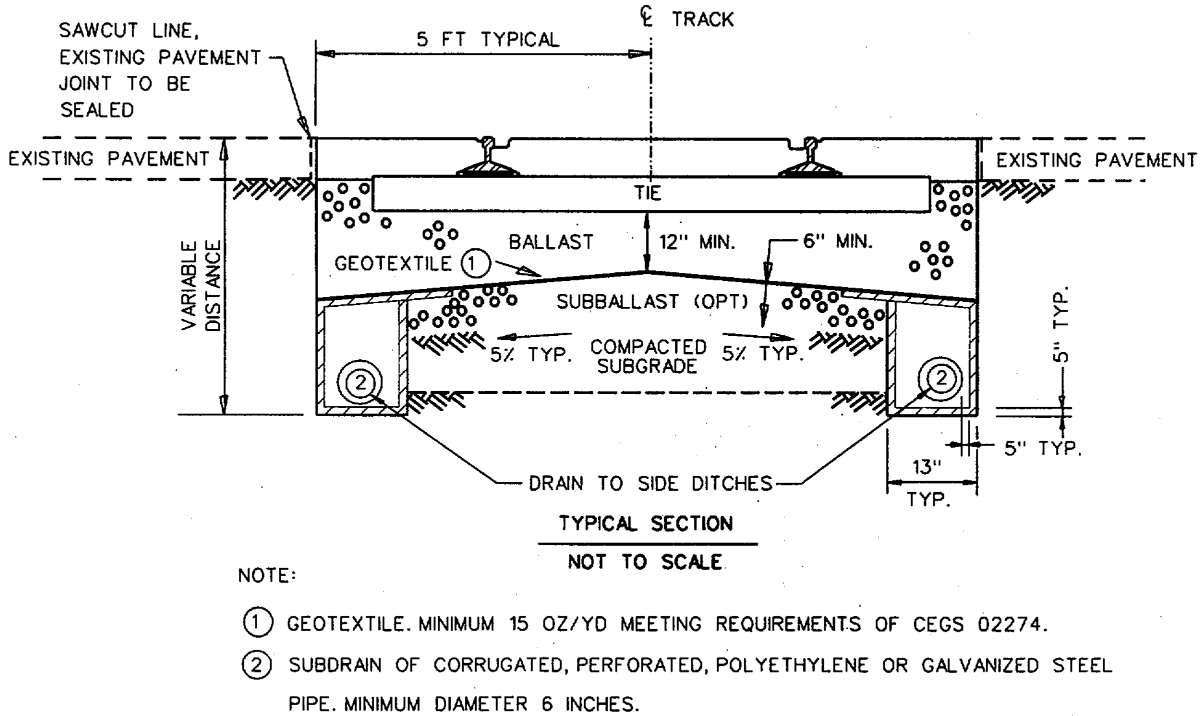


Figure 6-32. Typical Geotextile/Subdrain Installation for Vehicle Road Crossings.

c. Application. As rail crossings are expensive and require more maintenance than standard track, track layouts should be designed without the need for tracks to cross unless this is clearly necessary.

6-17. Bridges.

a. Types. Railroad bridges may be classified by deck type: open deck or ballast deck. In a typical open deck bridge, every fourth tie is bolted directly to the structure, thus in effect, the track becomes part of the bridge. In a ballast deck bridge, a standard track and ballast section are supported on a solid floor. The ballast deck has the advantage of allowing the track across the bridge to be lined and surfaced in the same fashion as standard track.

b. Design Procedures. When a bridge is required, the bridge structure will be designed by a practicing railroad bridge engineer in accordance with the AREA manual for timber structures, concrete structures, or steel structures. The AREA manual provides background and commentary on railroad bridge design practices.

c. Basis for Design. The design of railroad bridges is based on two main factors: the magnitude of applied loads to the bridge and the expected level of traffic (or number of stress cycles) over the design life of the bridge. One stress (or load) cycle is defined by one application and release of loading on a bridge member.

d. Cooper E Series Loading.

(1) The design live load is expressed using the Cooper E series loading configuration adopted by the AREA about 1905. Figure 6-36 illustrates a unit El axle loading. Higher loadings are obtained by multiplying each load by the same constant; wheel spacings do not change. Thus, an E60 loading would show the largest axle loads as 60,000 lbs.

(2) To allow an easy comparison of permissible in-service loading (or rating) over the life of a bridge with the loads used in their original design, and to compare the effect of different engine and car loads for either design or rating, the railroad industry kept the basic Cooper load configuration and used it to represent all bridge loadings and bridge capacity ratings.

e. Equivalent Cooper Loading.

(1) In use, the loading from a train of typical (or heaviest common) cars (the design train) is converted to the Cooper E loading which would have the same effect on the bridge.

(2) For a given design train, the equivalent Cooper loading (E value) will vary with train operating speed, bridge span length, and bridge design.

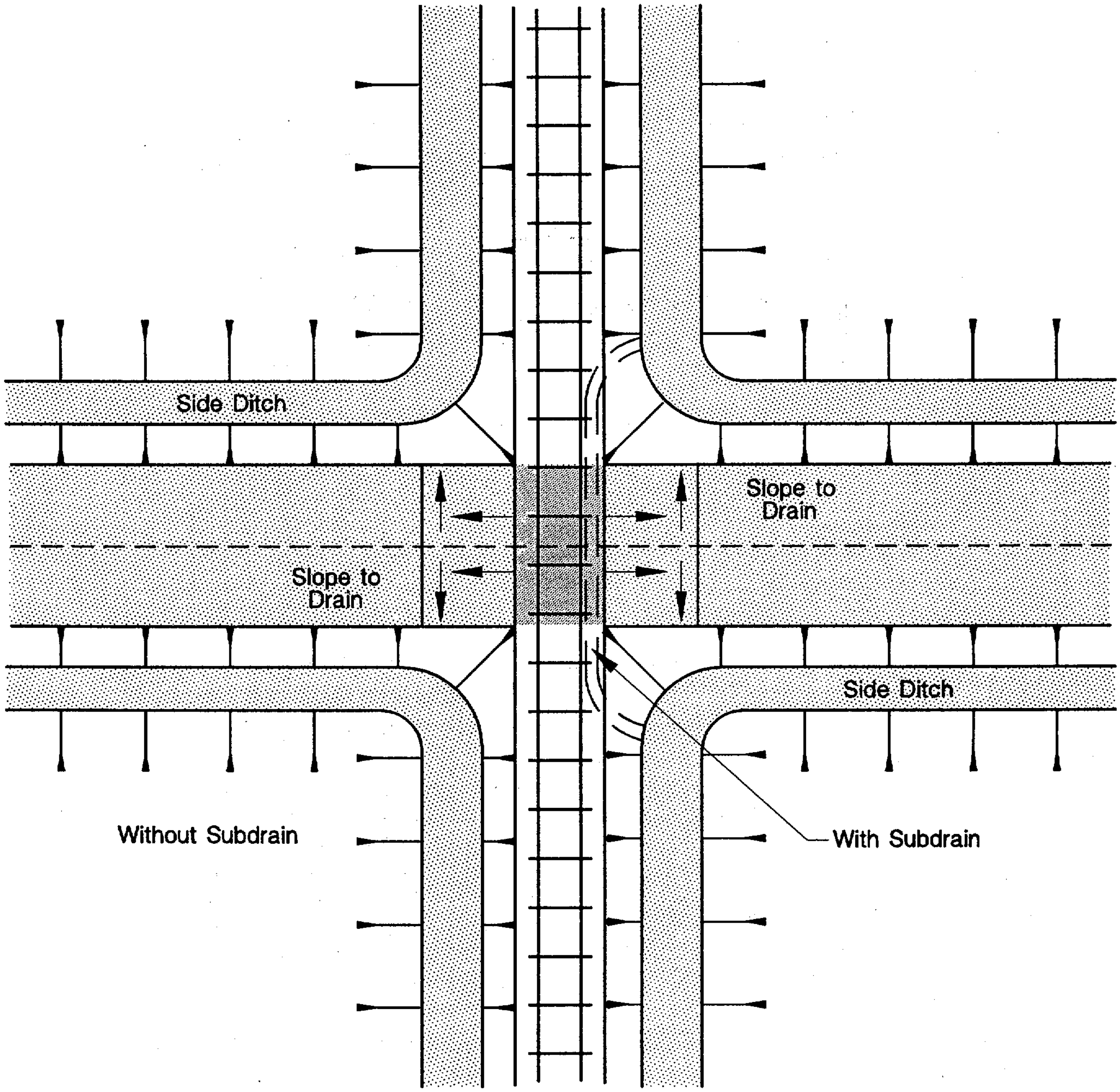


Figure 6-33. Typical Drainage at R Crossings.

(3) As the actual load distribution from current trains will differ from the Cooper configuration, the equivalent Cooper loading will not be a constant for all bridge components. Figure 6-38 shows the relationship between equivalent Cooper loading (at 60 mph) and span length for one type of steel bridge and for the loading shown in figure 6-39. As an example, figure 6-38 indicates that for a 60-foot span, the train in figure 6-39 produces an effect equivalent to a Cooper E48 load with respect to floor beam reaction, an E57 load with respect to end shear, and an E60 load with respect to bending moment.

f. AREA Standard Fatigue Stress Cycles. For fatigue, the standard AREA design assumes stress cycles from 100 trains per day, with 150 cars each (loaded up to 315,000 lbs gross weight), traveling at speeds up to 60 mph, every day for 80 years.

g. Design Live Loads.

(1) As the standard AREA fatigue loading is exceptionally high for most military railroad lines, designers should use the design live loading in table 6-8, which is based on the recommendations in the AREA manual. This loading is a general recommendation for span lengths up to about 75 feet. Actual design live loading may be adjusted to accommodate span length,

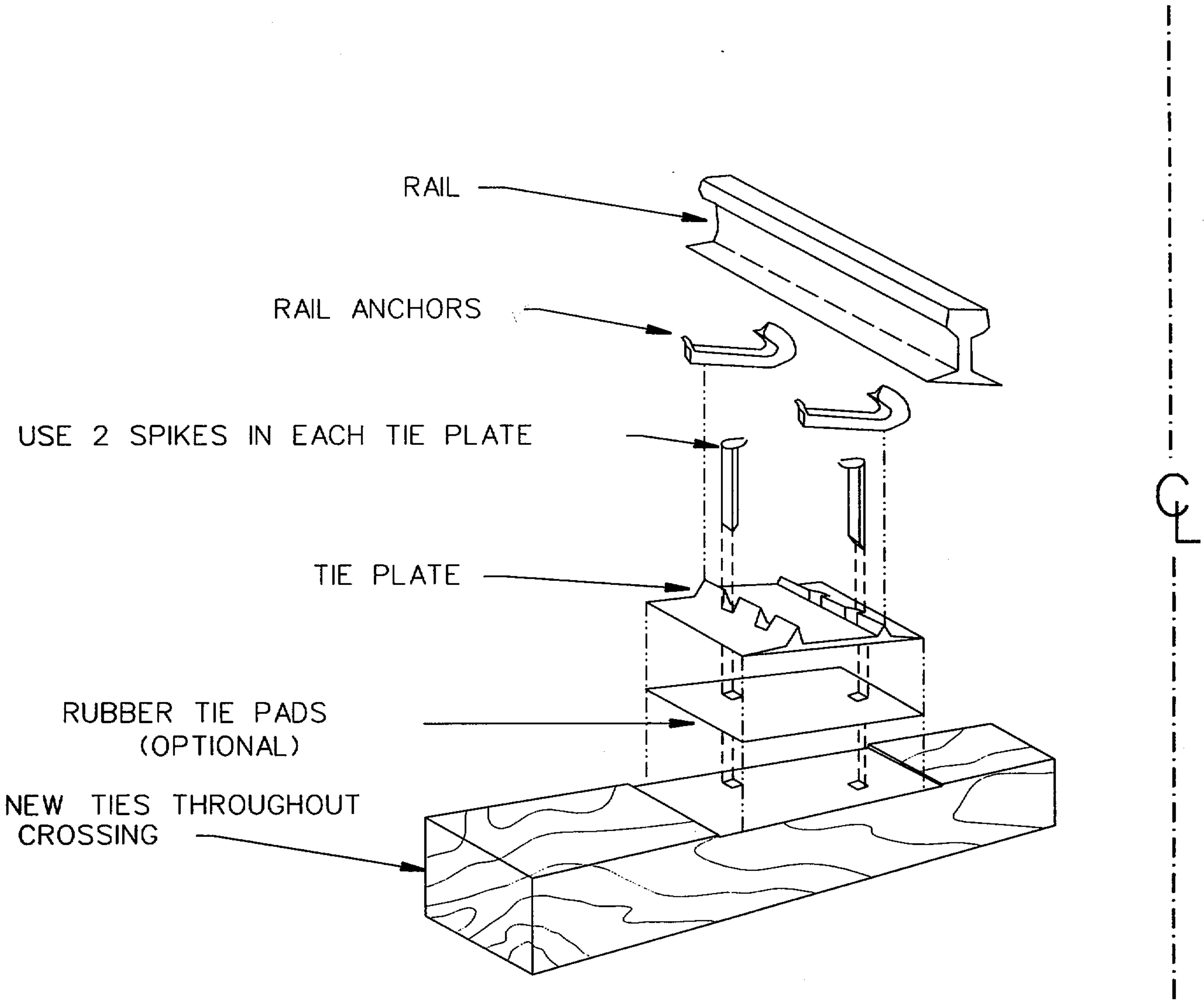


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Figure 6-34. Recommended Track Construction for Road Crossings.

structure design characteristics, and other variables.

(2) Traffic over most military railroad bridges does not exceed 5 MGT per year, thus the 0-5 MGT category of table 6-8 usually applies. To exceed this lower level, a bridge would have to experience an average annual passage of 38,000 loaded 100-ton cars (104 per day) or 26,500 loaded 140-ton cars (73 per day) throughout the life of the bridge.

h. Walkways. When bridges are located in areas where switching movements are made and at other locations where it is either useful or necessary for people to walk alongside a train (or cut of cars), walkways must be provided on at least one side of a bridge. Where people must have access to both sides of the track when a bridge is occupied, walkways must be provided on both sides. (Workers must never be expected to cross the track by going under cars, crossing over couplers, or climbing over cars).

i. Tie Pads. On open deck bridges, installation of rubber tie pads between the tie and tie plate is recommended.

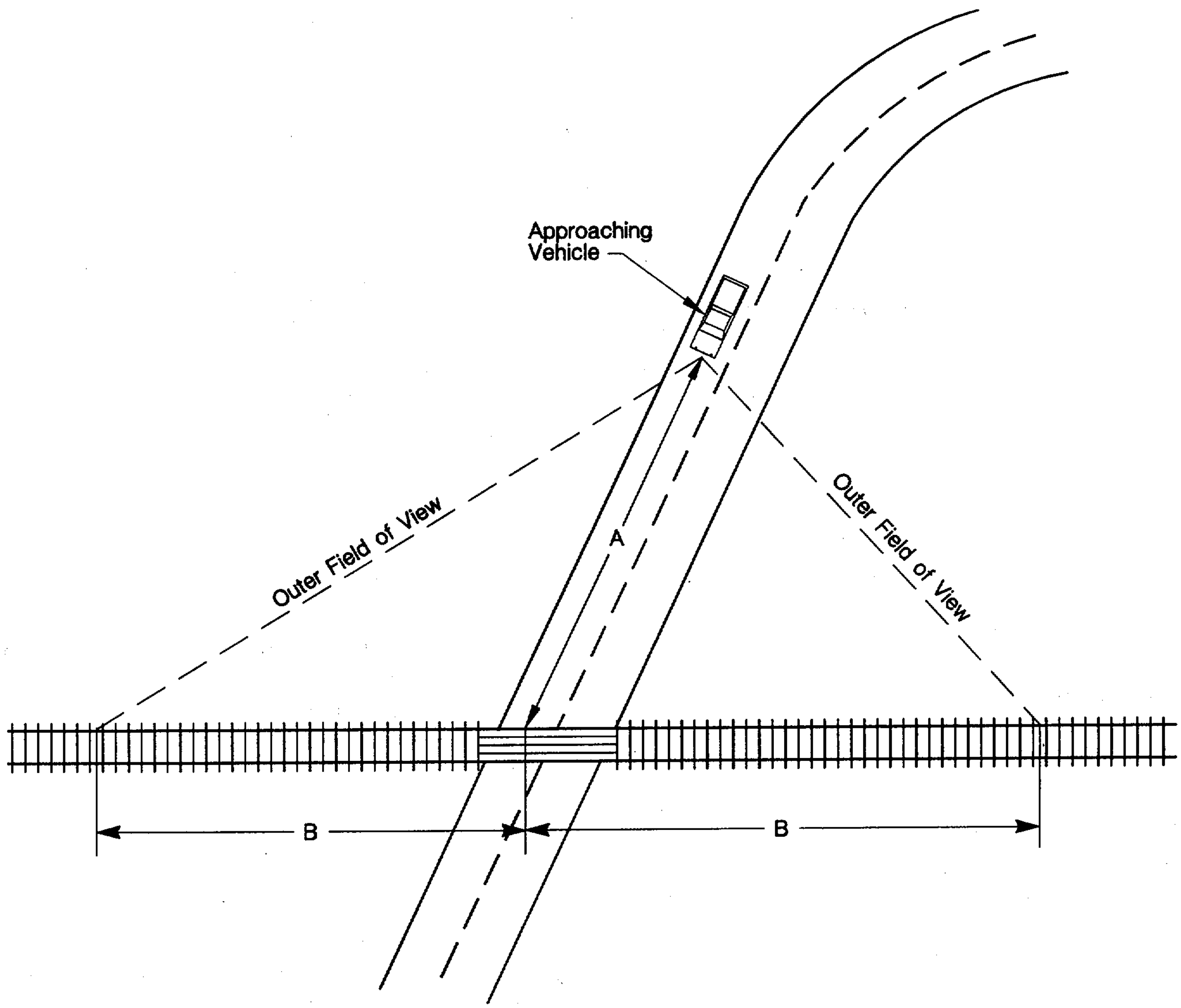


Figure 6-35. Clear Crossing Visibility Area for Approaching Vehicles.

6-18. Miscellaneous Track Appliances.

a. Derails.

(1) Application and Type. Derails are commonly used on spur tracks or sidings to prevent runaway cars or unauthorized entry onto the m; track. Derails are also used to protect stand equipment stored on a track. Three different types are the switch point derail, permanent hinged sliding derail, and portable derail.

(2) Location. Derails should be located so that after running over the derail, a car would stop before reaching the point requiring protection This distance depends mainly on track length a gradient. Figure 6-40 illustrates derail placement.

(3) Size and Designation. Derails must ordered for the size of rail on which they are to be installed. The number of the derail usually indicates the distance (in inches) from the top of the rail to the top of the tie (including tie plate thickness). Derails generally come in even 1 in. sizes and can be shimmed up to 0.5 in. in height (or the ties on which the derail is attached can be added up to 0.5 in. deep) to accommodate height variations.

(4) Direction. Derails are designed as either left-hand or right-hand. The proper direction is determined by looking in the direction that the rolling stock to be derailed would be moving. A right hand derail is installed on the right hand rail and derails the cars off the right side of the track, while a left-hand derail is installed on the left-hand rail and always derails to the left.

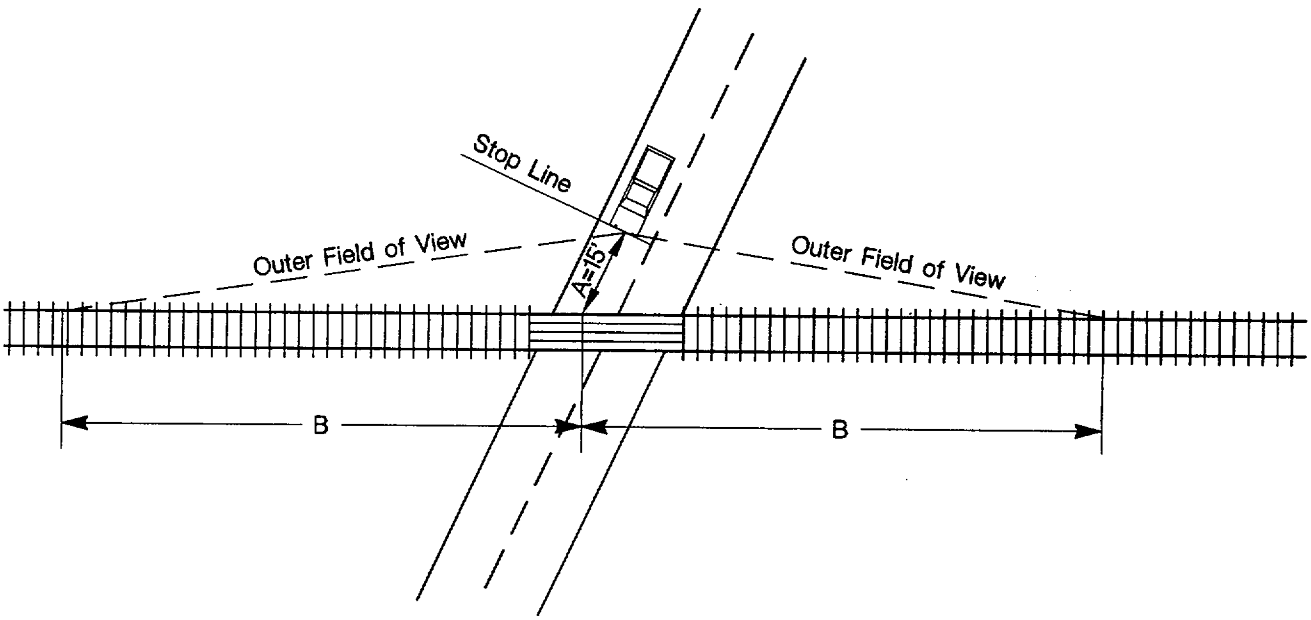


Figure 6-36. Clear Crossing Visibility Area for Stopped Vehicles.

b. Bonded and Grounded Track.

(1) Wherever cars carrying fuel, ammunition, or other flammable or explosive materials are unloaded, or where track is located adjacent to electrical equipment, the rails (and related track materials capable of conducting electrical current) must be bonded, grounded and insulated from the remaining track. This bonding and grounding helps prevent the discharge of static electricity during the loading or unloading of these hazardous materials. General requirements for bonding and grounding are given below; additional details are found in the AREA manual.

(2) When a side track, or section of running track, is to be bonded and grounded, an insulated joint should be provided on each rail at the first rail joint beyond the turnout of the adjacent main track at either end of the main track. The rails at all other joints in the track beyond or between the insulated joints will be bonded together with bond wires and both rails of the bonded track will be connected by grounding connectors to a single driven ground rod.

(3) An exothermic type rail bond ("cadweld bond") is recommended for the application of rail bonds on military track. Bond cables should be flexible bare copper stranded 1/0 AWG cables with preformed ends and should conform to the applicable requirements.

(4) Grounding rods should be 0.75-in. diameter copper clad steel rods or 1-in. diameter zinc coded steel rods. The minimum length of ground rods should be 8 ft. Ground rods should be driven vertically for their full length and the top of the ground rod should be located a minimum of 12 in. below the top of the subgrade at the toe of the ballast slope. The maximum allowable resistance grounded rail or structures is 25 ohms.

(5) All electrical connecting hardware should bronze pressure type materials and have no rotating parts coming in direct contact with the conductors.

(6) Rail cross bonds are required to bond the two rails together. Rail cross bonds should be stalled using exothermic type bonds and 1/0 AWG flexible bare copper stranded cable. The cross bond should be applied to the rail head or rail web and the cable for the cross bonds installed minimum of 12 in. below the bottom of the ties.
One cross bonded ground rod should be installed .
100 ft intervals along tracks designated for the loading and unloading of fuel, ammunition and her volatile or hazardous materials.

(7) Defective bonds will be removed by shear cutting old cables immediately adjacent to the weld or pin. Flames or torches will not be used to !move defective or out-of-service bonds.

(8) Where overhead power lines in excess of 00 volts cross over the track, the rails will be lade electrically continuous and grounded for a stance of 150 feet on each side of the power lines.

c. track Scales.

(1) When required, track scales will be designed and installed in accordance with the AAR Scale Handbook, which appears as an appendix in Le AREA manual.

Table 6-7. Clear Visibility Distance at Road Crossings.

Clear Track Visibility Distance B for Vehicle at 15-foot Stop Line							
Train Speed Limit (mph)	10	15	20	25	30	35	40
Visibility Distance: B (feet)	200	300	400	500	600	700	800

Note: See Figure 6-36.

Clear Crossing Sight Distance A for Approaching Vehicle										
Vehicle Speed (mph)	10	15	20	25	30	35	40	45	50	55
Clear Sight Distance A(feet)	70	100	135	175	225	275	350	420	500	600

Clear Track Visibility Distance B for Approaching Vehicle

Train Speed) (mph)	**Vehicle Speed (mph**									
	10	15	20	25	30	35	40	45	50	55
10	60	70	80	90	100	110	120	130	140	150
15	90	105	120	135	150	165	180	195	210	225
20	120	140	160	180	200	220	240	260	280	300
25	150	175	200	225	250	275	300	325	350	375
30	180	210	240	270	300	330	360	390	420	450
35	210	245	280	315	350	385	420	455	490	525
40	240	280	320	360	400	440	480	520	560	600

Note: See Figure 6-35.

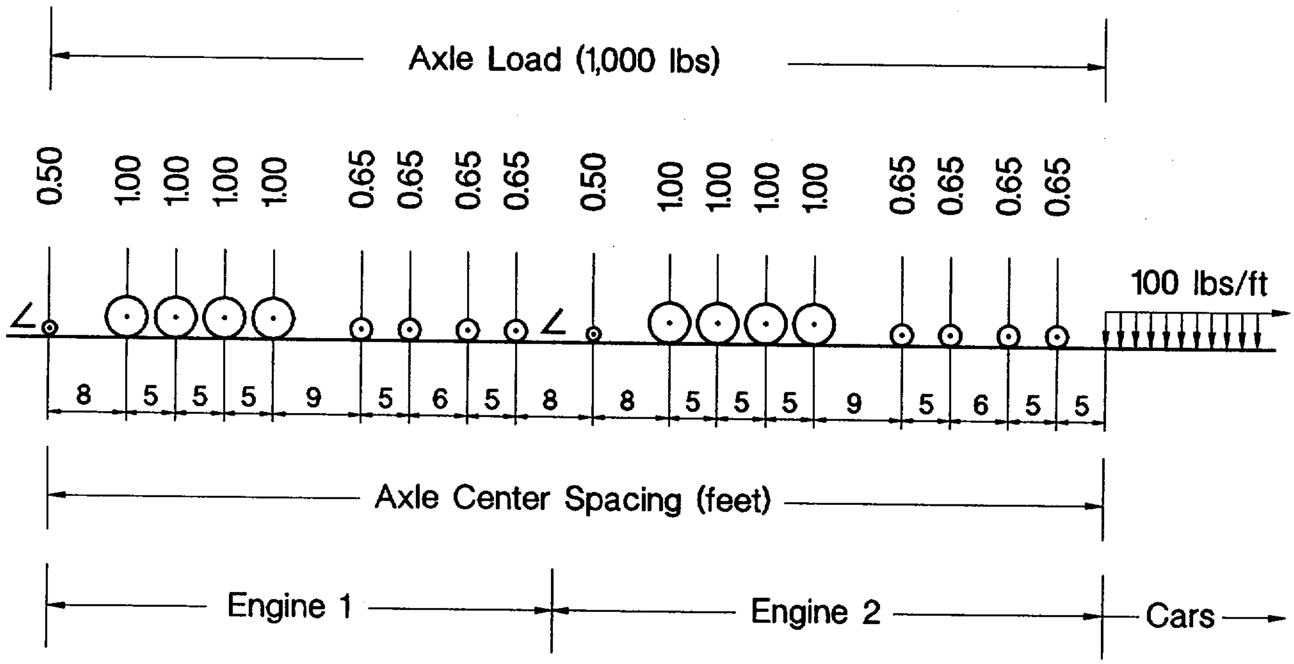


Figure 6-37. Cooper Load Configuration for Bridges.

(2) The design and construction of track scales is best performed by a commercial firm that specializes in design, fabrication and construction of railroad track scales.

d. Bumping Posts and Wheel Stops.

(1) Bumping posts, wheel stops or timber and earth mounds should be used at the open end of all stub tracks to prevent cars from rolling off the end of the track.

(2) Where it is not critical that railroad cars be absolutely stopped at track ends to protect personnel, facilities, or parked vehicles and equipment, and where no other hazards are present, consideration should be given to using low earth mounds or some type of wheel stop at the end of the tracks rather than coupler-height, solid bumping posts or obstructions.

e. Roadway Fencing. The character of the land use of property adjacent to the railroad and security requirements will govern the need for fencing along the right-of-way lines. The installation Physical Security Officer should be consulted to ensure that security fencing requirements are covered in the design.

f. Snow Fences. The AREA manual provides guidance on the application and construction of snow fences and other measures to minimize snow drifting on the track.

g. Cattle Guards. In areas where livestock or other large animals could enter the railroad right-of'-way at road crossings, cattle guards may be necessary.

Two Six-Axle Locomotives Followed by 100-Ton Boxcars

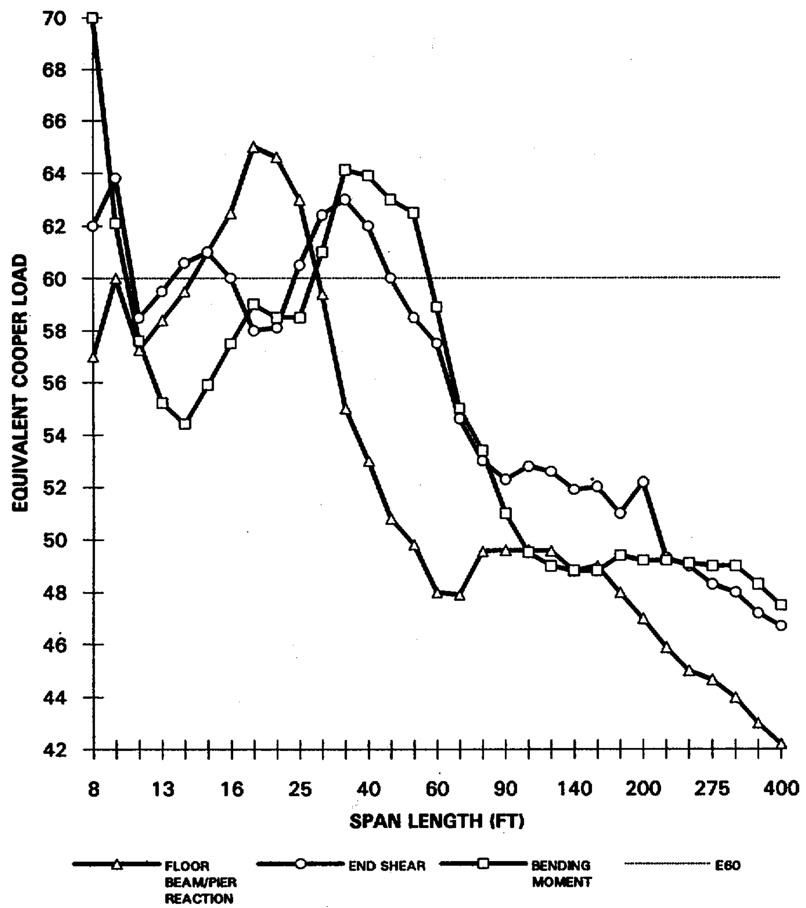


Figure 6-38. Variation in Cooper E Value with Span Length.

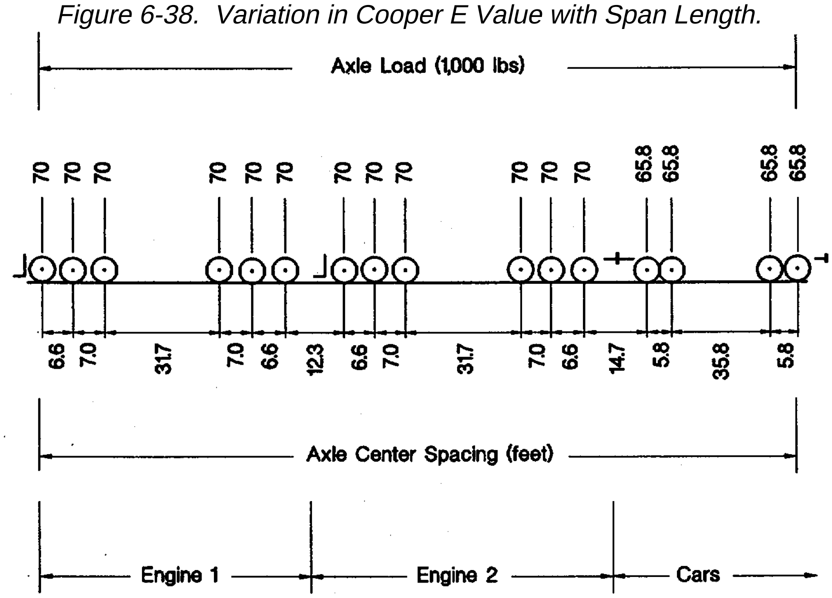
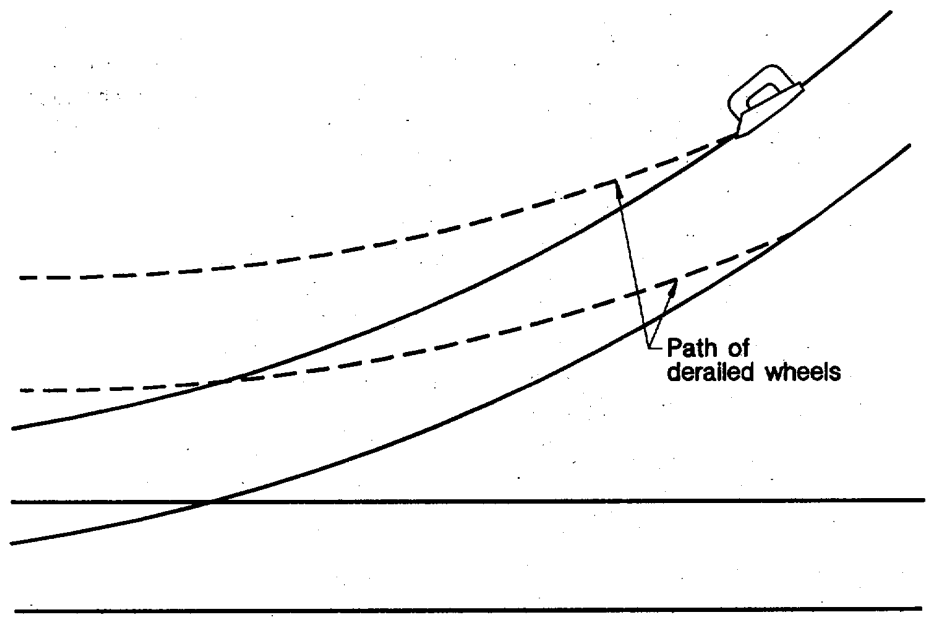


Figure 6-39. Loading Diagram for rain of 100-Ton Boxcars.

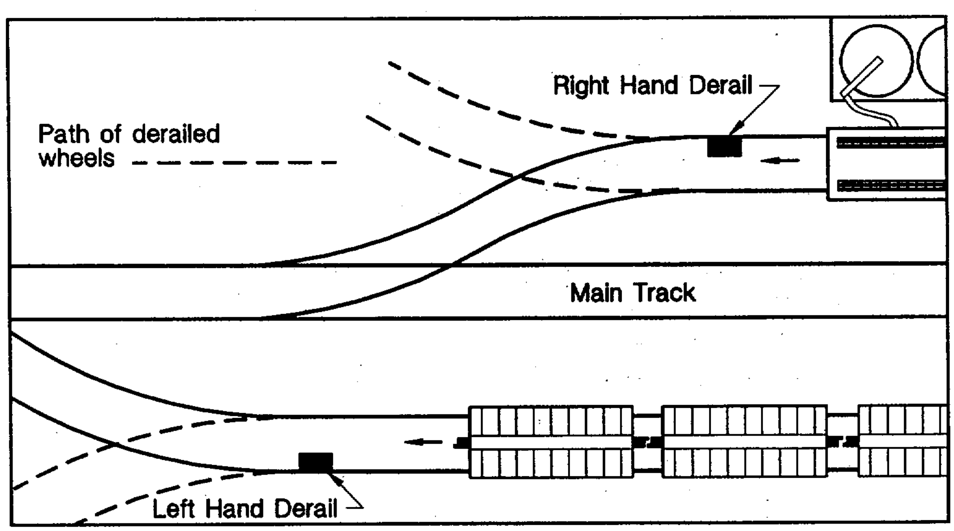
Table 6-8. Recommended Cooper Design Load for Bridges.

Annual Traffic Volume (Million Gross Tons)	Recommended Cooper Design Load For Car Capacity Up To:		
	100 Tons	120 Tons	140 Tons
0 to 5	E 40	E 50	E60
5 to 15	E 60	E 65	E72

Note: 1 million gross tons approximately equals 7,600 loaded 100–ton cars or 5,300 loaded 140–ton cars.



a. Location of Derail on a Curve.



b. Derails Protecting a Main Track.

Figure 6-40. Location of Derails.